AD-A118 595 MIDDLESEX RESEARCH CENTER INC WASHINGTON DC F/G 13/12
EFFECTS OF METRIC CHANGE ON SAFETY IN THE WORKPLACE FOR SELECTE--ETC(U)
APR 82 J M LEFANDE, J L POKORNEY AA-80-SAC-X8605
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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: None	2. GOVT ACCESSION NO.: AD-A118595
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Effects of Metrication on Safety in the Work Place for Selected Occupations	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER: None
7. AUTHOR(s): Judith M. LeFande, Joseph L. Pokorney	8. CONTRACT OR GRANT NUMBER(s): AA-80-SAC-X8605 ~~AA-80-SAC-X8605~~
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Middlesex Research Center, Inc. 3413½ M Street, N. W. Washington, D. C. 20007	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: None
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of Research, Office of Research, Coordination and Planning, United States Metric Board, 1600 Wilson Blvd., Ste. 400, Arlington, Va. 22209	12. REPORT DATE: April 1982
	13. NUMBER OF PAGES: 131
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: Not Applicable

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Metrication, Occupations, Safety, Occupational Hazards and Exposure, Measurement Sensitivity, Safety engineering, Unions, OSHA, NIOSH, Labor Statistics, Industrial Safety Programs, Training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study assesses the potential safety issues of metric conversion in the workplace. A purposive sample of 35 occupations based on injury and illnesses indexes were assessed. After an analysis of workforce population, hazard analysis and measurement sensitivity of the occupations, jobs were analyzed to identify potential safety hazards by industrial hygienists, safety engineers and academia.

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The study's major findings were as follows:

o No metric hazard experience was identified. In many instances, hypothetical scenarios were provided that characterized the potential for hazard, but none of these could be substantiated with actual experience.

o An increased exposure might occur when particular jobs and their job tasks are going the transition from customary measurement to metric measurement. Specific occurrences related to the tasks include: (1) worker judgment is exercised in using measurement; (2) communication of a measurement value between two workers; and (3) conditioned response in emergency situations involving measurement parameters.

o Well planned metric change programs reduce hazard potential. Industrial safety programs can reduced metric hazards. Involvement of professional safety experts in metric planning, metric training programs, and procedural analyses can reduce the potential exposure to hazards resulting from metric change.

o Metric safety issues are unresolved in the aviation industry. At the present time, the aviation industry is experiencing increase usage of metric measurement at the international level. Many safety issues related to aviation's adaptation of metric measurement can be identified in U.S. periodicals, but these have not yet been resolved nor has a comprehensive aviation conversion plan been developed and endorsed by the industry.

EFFECTS OF METRIC CHANGE ON SAFETY IN THE WORKPLACE FOR SELECTED OCCUPATIONS

FINAL REPORT

Prepared by

MIDDLESEX RESEARCH CENTER, INC.

Prepared for

THE UNITED STATES METRIC BOARD

MA-80-SAC-X0605
Contract Number ~~MA-80-0605~~

21 April 1982

This report was prepared by Middlesex Research Center, Inc. under Contract No. AA-80-8605 for the Department of Commerce. Its content is not necessarily endorsed by the United States Metric Board or the Department of Commerce. Middlesex Research Center, Inc. is solely responsible for its content.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LISTING OF FIGURES AND ATTACHMENTS

LISTING OF FIGURES AND ATTACHMENTS

(continued)

SUMMARY

INTRODUCTION

With the passage of the Metric Conversion Act of 1975 (P.L. 94-168), the U.S. Congress established a national policy of planning and coordinating the increasing voluntary use of the metric system. It also established the U.S. Metric Board to plan and coordinate voluntary conversions to the metric system.

The U.S. Metric Board has been directed by Congressional mandate to conduct research; publish the results of such research; and recommend to the Congress and the President such action as may be appropriate with regard to unresolved problems, issues, and questions relating to metric conversion in the United States. This study, "Effects of Metric Change on Safety in the Workplace for Selected Occupations", was undertaken in response to a previously identified need for a detailed analysis of safety issues related to metric conversion.

BACKGROUND

The purpose of this study was to identify those occupational tasks that, when subjected to measurement change, would most likely create worker safety hazards and public safety hazards. No previous research has been done in this area.

The occupations studied were both hazardous and measurement sensitive. The percentage of the entire workforce within each occupation and the incidence of worker injury were used as criteria for further limiting the number of occupations studied. Finally, occupations in which workers are not required to make decisions based on knowledge of measurement were also eliminated.

The study methodology was developed with the assistance of an Advisory Committee; the Committee members selected are experts in safety, labor, management, and government. Various data gathering methods were considered, including mail surveys, telephone surveys, and field visits to various companies. The university-sponsored <u>limited</u> forum was selected as the best means of collecting data because, in <u>one trip</u>, the study team could get information from experts who represented the selected occupations, as well as the academic community, labor, government, and private industry.

The major requirement for the forum participants was to perform job hazard analyses on the occupations being studied and to hypothesize the effects of the introduction of measurement change within the job. These data were then compared with information gleaned from the literature and agency interviews, and conclusions were drawn.

FINDINGS AND CONCLUSIONS

The research team found that almost all of the most hazardous occupations are also measurement sensitive. The study further concluded that this is only an issue if the measurement is related to the hazardous task, or when the worker must make a decision based on a measurement. In some cases, such as trash collectors, the two are not related. Airline pilots, although not identified as a hazardous occupation by statistics, are heavily involved in measurement and can affect public safety.

Major findings of the research effort are:

- There is little or no public information available relating human factors to accidents. OSHA, the only agency collecting such information, investigates a very small number of accident injuries in the workplace.

- Safety officers and industrial hygienists expressed concern that in the decision to convert to metric measurement, industry management failed to involve safety personnel in the conversion planning process.

- Well-planned metric change programs within industry can reduce potential hazards. Plans that minimize the simultaneous use of both metric and customary units and also provide adequate occupational training can reduce the impact of potential safety hazards associated with metric change.

- Metric issues are unresolved in the aviation industry. As a result of these unresolved issues, the potential for an aviation hazard resulting from the continued use of both metric and inch measurement units in international aviation continues to exist.

Through research and analysis it was determined that, in all cases, hazards in the workplace can be averted through safety training and awareness programs. For instance, if a crane operator is aware that a steel beam might be marked in metric tons rather than in the customary 2,000-pound units, then he may be more cautious about exceeding the limits of his crane's boom and sling, and will adjust the angle accordingly.

RECOMMENDATIONS

As a result of the findings of this study, the research team formulated several recommendations.

- The U.S. Metric Board should consider safety issues when reviewing sector plans. Specific action should be taken to ensure that appropriate safety professionals from industry and government have been involved in the development of those plans.

- The American National Metric Council should involve safety professionals in its sector planning activities. Through its highly organized sector planning process, ANMC provides a sounding board for all issues associated with a sector conversion plan. However, without specific actions to ensure the involvement of safety professionals, it is possible that safety hazards associated with metric change might be overlooked.
- The U.S. Metric Board should encourage the inclusion of safety professionals in the development of all metric planning activities for Federal agencies.
- The U.S. Metric Board should initiate some research effort into human factors and training for airline pilots, with input from ALPA and the FAA as well.

I. SAFETY HAZARDS STUDY

This report covers the research completed by the Middlesex Research Center, Inc. (MRC) staff to identify the potential safety hazards for workers and for the public in general as a result of the introduction of metric conversion in the workplace. The report includes a discussion of the need for the study, the research design employed, the data obtained, analyses of the data, and the conclusions and recommendations of the research staff.

In this section of the report, the reader is introduced to the study background, the history of worker safety research, the scope of the study, and the study objectives.

A. STUDY BACKGROUND

The Metric Conversion Act of 1975 (P.L. 94-168) established the U.S. Metric Board as an independent Federal agency responsible for coordinating the voluntary conversion of the United States to the metric system. In passing the Act, the Congress declared that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish the United States Metric Board to coordinate the voluntary conversion to the metric system.

The U.S. Metric Board consists of 17 members who are representative of the various sectors of the United States' economy, including representatives for engineers, scientists, the National Association of Manufacturers, the U.S. Chamber of Commerce, the AFL-CIO, the Governor's Conference, small business, construction, the National Conference on Weights and Measures, educators, and consumers. Among the various responsibilities and functions mandated in the Law, the Board is "... to consult with and to take into account the interests, views, and conversion costs of U.S. commerce and industry ..." The Act instructs the Board in Section 6(8) "to collect, analyze, and publish information about the extent of usage of metric measurements; evaluate the costs and benefits of metric usage; make efforts to minimize any adverse effects resulting from increasing metric usage." Section 6(9) directs the Board "to conduct research, publish results and recommend to Congress and to the President such actions as may be appropriate to deal with any unresolved problems, issues and questions pertaining to metric usage and conversion."

It is the policy of the U.S. Metric Board that metrication is to proceed by the voluntary, coordinated decisions of each segment and sector of our society. The role of the Board is to ensure that changeovers take place in the most economical and effective way and to encourage all interested parties to participate in the planning process.

As a result of Public Law 94-168, the U.S. Metric Board was authorized to undertake certain types of research regarding the effects of metric conversion. Under the leadership of its research committee, the U.S. Metric Board has determined that the impact of metric conversion on individual workers is an important area of research.

During October of 1979, the U.S. Metric Board began its initial research in the area of Worker Tools and Training. This (1979-1980) study, entitled "The Effects of Metric Conversion on Measurement and Dimensional Sensitive Occupations", was conducted in two phases. The first phase analyzed the Dictionary of Occupational Titles (DOT) to determine which occupational areas seemed to be measurement sensitive. These occupational areas were used to formulate research objectives for future studies. The results of this analysis were used to identify the initial goals for the Phase II study of tool and training issues. The results of Phase IA were also used as a resource for this study.

In May of 1981, Middlesex Research Center completed its study of the "Effects of Metric Change on Workers' Tools and Training"; in July, MRC presented its findings to the U.S. Metric Board at its meeting in Charlotte, North Carolina. Part of that presentation included a recommendation that potential worker safety hazards be explored. In September, the Metric Board requested that the study of worker safety hazards be continued since the "Effects of Metric Change on Workers' Tools and Training" was not intended to focus on a detailed, in-depth analysis of safety issues. Based on information that was gathered during on-site visits, MRC had determined that there was a potential for increased safety hazards in certain job tasks. For example, a worker whose job involves lifting heavy equipment with an overhead crane might experience difficulty in safely estimating the weight of a load if he is accustomed to dealing with customary weights and the markings on the loads have been changed from U.S. tons to metric tons. There were a number of specific job tasks that appeared to be susceptible to increased safety problems as a result of metric conversion; therefore, based upon their findings, the U.S. Metric Board initiated this study to examine the issues of "Effects of Metric Change on Safety in the Workplace for Selected Occupations".

Although it is in the purview of the U.S. Department of Health and Human Services' National Institute of Occupational Safety and Health to research the hazards in the workplace, it was decided that the issue of metric conversion and the associated safety concerns should first be studied by the Metric Board's Office of Research. The issue of metric conversion in the workplace, if approached as the introduction of a new technology, could then be studied from the standpoint of people who are most familiar with the various aspects and implications of metric change and who are also well informed on the issues of worker safety.

B. HISTORY OF THE WORKER SAFETY RESEARCH

Since the first cave person cut himself while striking his flint, getting injured on the job has been a part of human working conditions.

Today at least 14,000 persons are killed in work accidents every year. Sometimes it seems little has changed during man's long trek out of the caves and into the factories. But there has been progress, however slow.

In 1914, the Office of Industrial Hygiene and Sanitation was created as a part of the Public Health Service. At this time there was a growing concern about conditions in the nation's workplaces -- from Colorado mines to New York City sweatshops. Concurrently, industry and the fledgling labor unions were developing the discipline of occupational health. The early work of the Public Health Service included investigations of chest diseases among miners, tuberculosis in garment industry workers, and radium poisoning among watch dial painters. During the 1930's, PHS began to issue periodic reports on the causes and duration of industrial sickness and related absenteeism. These documents helped to stimulate the growth of in-plant health programs in private industry.

Despite evidence that occupational diseases and accidents were a major problem, Federal programs remained at a marginal level until World War II. However, as demands were made for increased productivity, some credence was given to the importance of industrial hygiene and occupational medicine. Protecting employee health in government-owned, privately-operated munitions plants became a major activity of the Public Health Service during this period. After the war, interest in occupational health waned, but the problems remained.

Over the years, a variety of laws provided limited protection for workers in certain dangerous trades and those working for businesses under Federal contract, but these laws were not vigorously enforced.

In 1968 Congress introduced proposals for a broad occupational safety and health act. However, a coal mine disaster that took 180 lives narrowed the focus to mining safety issues and resulted in the Federal Coal Mine Health and Safety Act of 1969. Interest, especially among labor unions and the media, was now aroused about occupational health problems in general; and the following year, the Occupational Safety and Health Act of 1970 was passed by Congress. For the first time, the Federal government had broad authority to investigate workplace illnesses and accidents and to correct them.

The Occupational Safety and Health Act created three new governmental agencies: the Occupational Safety and Health Administration (OSHA) within the Department of Labor, which sets and enforces health and safety standards in the nation's workplaces; the National Institute for Occupational Safety and Health (NIOSH) in the Department of Health and Human Services, which is a research agency that might be called the scientific conscience of the Federal occupational health and safety program; and the Occupational Safety and Health Review Commission (OSHRC), which settles disputes arising from enforcement of the Act.

As new technologies are introduced in the workplace, continuing research is necessary to assure that workers are protected. Metric

conversion introduces the potential for change in working procedures and worker miscommunications. It rightly deserves the attention of researchers who are familiar with the issues of metric change and human factors in the workplace and the relationship of these issues to Federal regulations and responsibilities.

C. SCOPE OF THE STUDY

In order to make a valid identification of potential safety hazards or the absence of such hazards related to metric conversion, it was necessary to narrow the focus of the study to a manageable size. To do this, the criteria considered included:

1. hazardous occupations

2. measurement sensitive occupations (see Figure 1 at the end of this section)

3. occupations in which hazard is related to measurement judgment and/or communication of that measurement judgment to other workers (see Figure 2 at the end of this section).

It was determined that the best approach to focusing the study of potential metric safety hazards was to develop a matrix that included hazardous, as well as measurement sensitive, occupations. The workforce of each occupation was then measured against the general working population to ensure that the number of workers within a particular occupation was sufficient to warrant its inclusion in the study.

The incidence of worker injury within each occupation was also considered in order to eliminate those occupations that, although they are hazardous, are so controlled through regulations and training that they do not contribute to worker accident statistics. An example includes the explosive device industry.

Occupations in which workers are not required to make decisions based on knowledge of measurement were also eliminated. It was assumed that in these occupations the conversion of a measurement system would have no effect on the workers' safety.

The result of the aforementioned processes is a group of occupations that encompasses a broad range of industry activities, including such jobs as sheet metal worker, crane operator, chemical processor, airline pilot, and automotive mechanic. All of these jobs were identified in a previous study as being measurement sensitive. Further, all of the jobs were identified as being hazardous and encompass a significantly-sized worker population. In addition, there is evidence that workers in these jobs must make decisions based on knowledge or communication of measurements. Some of these jobs were also included because of the potential for public safety hazards, a consideration that made them eligible for inclusion even when the worker population was small (i.e., airline pilots and crane operators).

D. STUDY OBJECTIVES

In changing the measurement system in the workplace from one with which people have long been familiar to one that is less familiar, there is a possibility that hazards will be introduced as well. The hazards could result from mismeasurement, misunderstanding a measurement, or miscommunication of the measurement between workers. The factor common to each case is based on the human learning theory, which allows the situation to be averted through training.

It is the objective of this study to identify those occupational tasks that, when subjected to measurement change, would most likely create worker safety hazards. In the process of seeking out those jobs that are either measurement sensitive or hazardous (or both), the jobs in those categories that could affect public safety as well were also to be identified.

The product of this investigation is a document that lists the occupational tasks that could be adversely affected by introduction of the metric system. It elaborates on the hazards that may occur and refers to the mechanism that is considered most appropriate to remove the hazard.

In addition to identifying potential metric-related job hazards, the research team also considered the issue of the cost of training and the cost of not training. However, due to the hypothetical nature of this study, it was decided that a cost case study would only reflect the known costs of safety training programs and the costs related to accidents. Although there is much data that accurately reports these costs, the absence of real "metric accidents" data makes the application less than scientific.

MEASUREMENT SENSITIVE DEFINITIONS

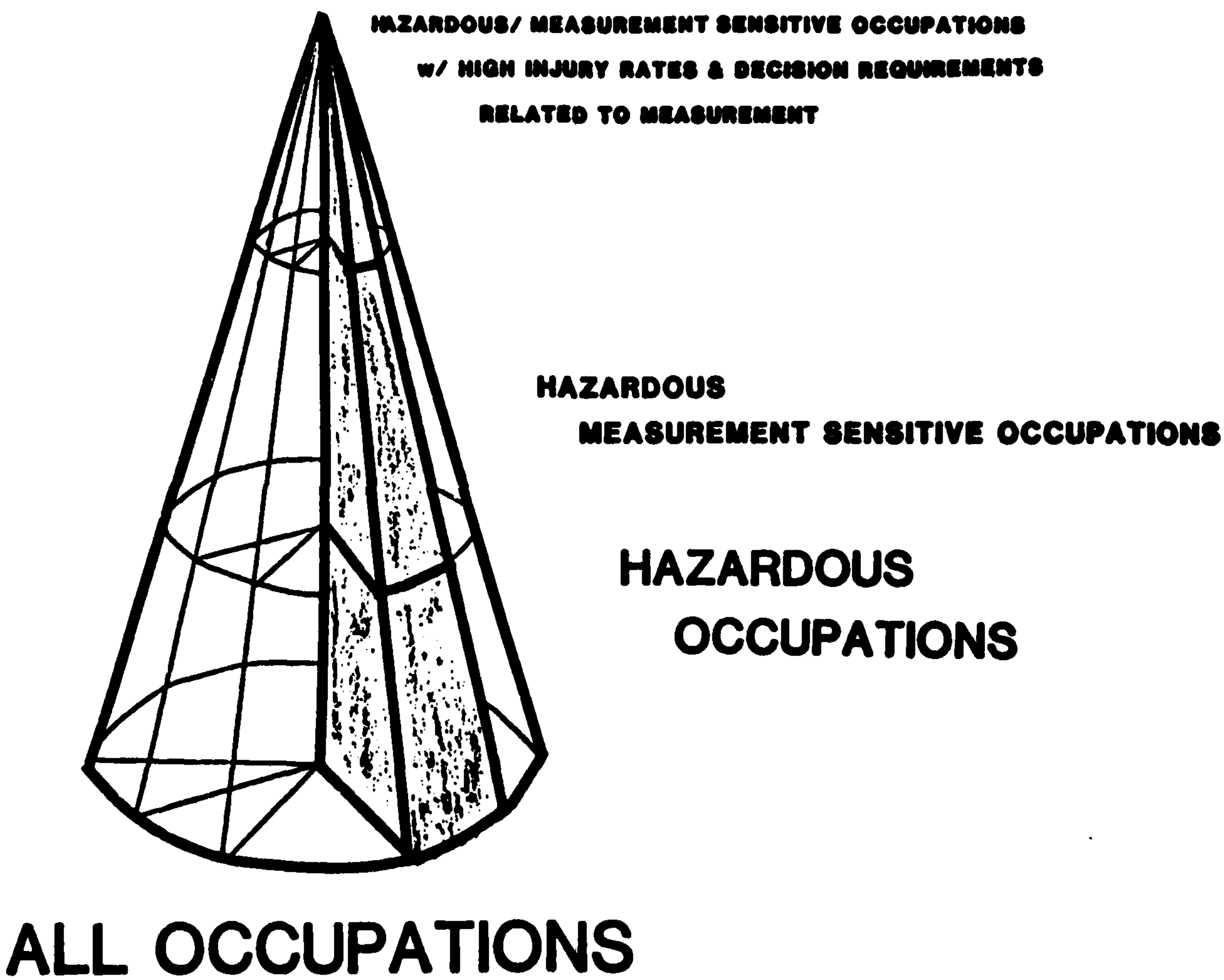
1. Measurement sensitive. Jobs that are measurement sensitive require the measurement of things and the use of tools or instruments involving measurements. Some examples are: a home economist who develops and tests recipes where measurement of the ingredients is involved; an industrial designer who prepares detailed drawings involving measurement dimensions; a parcel post clerk who determines the weight of parcels in order to apply the correct postage; a tool and die maker who produces parts from detailed drawings; or an automotive mechanic who uses a torque wrench or air gauge to measure various items and runs tests using a dynamometer to measure speed, fuel usage, exhaust emissions, etc.

2. Specification sensitive. This category includes those jobs that use things defined by standards and uniform specifications (i.e., sheet metal thickness, wire size, tool sizes, drill sizes, etc.). Examples of jobs in this category are: a punch press operator who tends one or more power presses and loads them with steel of a specified gauge; an electrician who uses wire specified by gauge; a machinist or mechanic who uses wrenches defined in inch or fractional inch sizes; or a drill press operator who changes drills from time to time but identifies the drill by the established drill number, letter, or fractional inch size and not by measurement of the drill diameter.

3. Process sensitive. This category includes those jobs that use measurement information in performing a job (for example, tabulation of inventory or maintenance of records in which measurement units are involved). Examples of this type of job are: medical records personnel who deal with patient information in measurement units, but do not actually perform the measurement; real estate agents who routinely use lot size and building size in real estate transactions, but do not themselves make the measurements of those items; a technical writer or technical proofreader processing material that includes technical content relating to measurement units; and inventory or stock clerk personnel who maintain records of material in measurement units, but do not themselves perform the measurements.

4. Not sensitive. These jobs do not require measurement activity or the use of measurement units in any of the above three ways.

FIGURE 2


HAZARDOUS/ MEASUREMENT SENSITIVE OCCUPATIONS
w/ HIGH INJURY RATES & DECISION REQUIREMENTS
RELATED TO MEASUREMENT
HAZARDOUS
MEASUREMENT SENSITIVE OCCUPATIONS
HAZARDOUS
OCCUPATIONS
ALL OCCUPATIONS

II. STUDY METHODOLOGY

This section contains a discussion of the mechanisms that were employed to obtain the data on which the study conclusions are based. The following is an outline of the study procedure.

A. Development of the Project Plan

B. Recruitment of the Advisory Committee

C. Project Methodology

D. Identification of Data Sources

   1. Federal and State Agencies

   2. Professional Associations

   3. Public Service Organizations

   4. Appropriate Academicians

   5. Interested Representatives of Organized Labor

E. Identification of Hazardous Occupations

F. Retrieval of Measurement Sensitive Occupations

G. Development of Hazardous/Measurement Sensitive Occupations Matrix

H. Refinement of Matrix with Consideration for Size of Worker Population and Relationship between Measurement and Hazard

I. Public Hazards

J. University Forums

   1. Development of Format

   2. Selection of Universities

The methods that were used to research the potential for safety hazards related to metric conversion in the workplace are a blend of standard data gathering interviews and the use of limited forums. This chapter describes the steps that were taken by the research staff to develop the

format and gather the information that was necessary to provide valid findings to the U.S. Metric Board on this issue.

A. DEVELOPMENT OF THE PROJECT PLAN

The Project Plan was developed by the research staff based on the best and most economical method of collecting the data needed. The plan outlined the project methodology, described the format for the advisory meetings, specified the data collection approach and stated the project reporting procedures (Attachment II.1 shows the schedule for these tasks).

B. RECRUITMENT OF THE ADVISORY COMMITTEE

An Advisory Committee was established early in the study in order to get advice from experts in safety, labor, management, and government and to ensure the integrity of the study plan.

By the time the Advisors met (the roster is shown as Attachment II.2), the research staff had identified the most hazardous jobs and had developed a matrix of hazardous and measurement sensitive occupations (Attachment II.3). In addition to reviewing the Project Plan, the Advisory Committee also worked on refining the matrix. The Committee members concluded that some of the occupations on the matrix were hazardous for reasons not related to measurement and narrowed the focus of the study to 10 occupations. The Advisory Committee also added two occupations that were considered to be of special concern, even though they were not on the matrix. These two additional occupations are Chemical Processing Workers and Crane Operators.

The Advisors agreed to be available for consultation as the study progressed and to review the draft conclusions. They agreed with the university-sponsored forum as the logical mechanism for data gathering.

C. PROJECT METHODOLOGY

The Project Plan was revised to include only two forums because of a contract schedule revision imposed by the Metric Board. It was agreed that although somewhat less information would be obtained, the quality of the forum participants' input could help to ensure the validity of the study conclusions.

1. Identify the most hazardous occupations

The most hazardous occupations were identified using statistical data from the Bureau of Labor Statistics and the National Safety Council, computer searches of the literature, and the expert opinions of industrial safety specialists.

2. Identify the measurement sensitive occupations

This task was done in the Worker Tool and Training Study. The occupational areas from the Dictionary of Occupational Titles that were identified as being measurement sensitive in that study were used for the current study (see Attachment II.4).

3. Hazardous/Measurement Sensitive Occupations Matrix

A matrix was developed using the data from 2 and 3 above. This matrix showed the worker population in order to identify the greatest number of workers facing both hazards and measurement sensitive tasks. This matrix, which identifies the occupations that may be both hazardous and sensitive, is shown in Attachment II.3.

4. The prioritization of occupations to study

The research team prioritized the occupations to be studied by use of weighting factors. The research staff established a weighting factor for the following:

- Hazard characteristics
- Measurement sensitivity characteristics
- Size of worker population
- Level of decisionmaking within job tasks
- Job/task relationship to potential public hazards.

An example of the weighting factor structure is shown in Attachment II.5.

5. Address Federal regulations affected by metric change

Selected Federal regulations that relate to the prioritized occupations were reviewed, and those regulatory areas that required changes for safe use of SI measurement language were identified.

6. Collect industry data

To maximize industry input to the study, MRC conducted two one-day forums on metric safety issues. The forums were geographically distributed throughout the U.S., and participants were solicited from industry, labor, and academia (see Attachments II.6, II.7, and II.8). Professional organizations and companies were selected to participate in structured forums and to be used as data sources.

7. Problem identification

Scenarios were developed illustrating the interrelatedness of worker mismeasurement and the creation of public hazard. A discussion of the mechanisms that could be employed to avert dangerous situations was incorporated into the scenarios.

8. Analysis and final report

Following analysis of the data, the research team submitted a draft final report to the U.S. Metric Board. This report included a description of the occupations studied, analyses of those occupations, identification of safety hazards, public safety issues, and recommendations for prevention of potential hazards.

D. IDENTIFICATION OF DATA SOURCES

A complete list of the data sources that were identified during this study is provided in Attachment II.6.

1. Federal Agencies

The Federal agencies that were identified as being valuable data sources for this study included:

- The Department of Labor's Bureau of Labor Statistics. This group was able to provide the research staff with volumes of information on the labor force and on the injury statistics gathered according to job classifications.

- The Department of Health and Human Services' National Institute of Occupational Safety and Health (NIOSH). NIOSH searched its files for similar studies (of which there were none). NIOSH also gave the research staff an overview and history of worker safety research.

- The Department of Transportation's Federal Aviation Administration. FAA Safety Standards' personnel and the Metric Coordinators responded to questions regarding the use of metric measurement in aircraft manufacturing and in air traffic control. They also provided the study team with FAA's draft metric conversion plan.

2. Professional Associations

The professional association that was contacted for the study was the American Society for Safety Engineers. The Association's research group reviewed its files for information on studies similar to this one, provided

the research team with contacts who are familiar with the occupations being studied, and arranged for the research team to meet with several of its members to test the study methodology.

3. Public Service Organizations

One public service organization that was particularly helpful was the National Safety Council. Their Accidents Facts Book provided valuable data that substantiated data obtained from the Bureau of Labor Statistics. The Canadian Safety Council, by telephone contact, provided information on Canadian industrial safety since the introduction of the metric system in Canada.

4. Academicians

Teachers in colleges and universities contributed to the study both as members of the Advisory Committee and as participants in the forums. All of the schools in the United States and Canada known to have graduate level safety programs were contacted. A list of these contacts is provided in Attachment II.7. Prominent among the schools that participated were Central Missouri State University and the University of Southern California.

5. Interested Representatives of Organized Labor

Representatives of some of the brotherhoods of labor were contacted and asked to participate in the study. A list of labor contacts is provided in Attachment II.8.

E. IDENTIFICATION OF HAZARDOUS OCCUPATIONS

The identification of the key hazardous occupations for the American workforce was done using three main sources of data:

1. The U.S. Department of Labor, Bureau of Labor Statistics' Supplementary Data Systems, July 1981
2. Accident Facts, 1980 edition, National Safety Council
3. Occupational Injuries and Illnesses in the United States by Industry 1978, U.S. Department of Labor, BLS, August 1980.

These data were reviewed by the safety engineering members of the research team. These sources for the data were used because they covered all industries and because the statistical bars are representative of the U.S. worker population. From the data, MRC gleaned facts that validated the establishment of a list of occupations that employ high numbers of workers who are injured on the job.

The data available through the Department of Health and Human Services' Occupational Safety and Health Administration were not used to any great extent in this study. Although this is the only known source of information on human factors related to worker accidents and injuries, the data are so limited in numbers that they cannot be considered representative. The issue of human factors was dealt with by the forum participants instead.

After analyzing the available statistics, the study team developed a list of 35 occupations that were considered most hazardous, both across the industries (NSC data base) and across the occupations (BLS data base). This list is provided in Attachment II.9.

F. RETRIEVAL OF MEASUREMENT SENSITIVE OCCUPATIONS

In an earlier study entitled, "Effects of Metric Conversion on Workers' Tools and Training", the Metric Board conducted research to determine which occupations are sensitive to measurement. This was done through an analysis of the job tasks that are part of the occupations listed in the Department of Labor's Dictionary of Occupational Titles (DOT). A list of the measurement sensitive two-digit code titles is provided as Attachment II.10. This list was further refined to identify the type of measurement sensitivity of each occupation. For this study, however, the generic category of "measurement sensitive" occupation was used.

G. DEVELOPMENT OF HAZARDOUS/MEASUREMENT SENSITIVE OCCUPATION MATRIX

Once the hazardous and measurement sensitive occupations were identified, a grid was devised that listed the hazardous occupations on the vertical axis. The measurement sensitivity was noted on the horizontal axis. Those hazardous occupations that had no measurement sensitivity were then eliminated from the study. Analysis showed that almost all hazardous occupations were indeed measurement sensitive. This posed a problem because the size of the group of occupations was too large to study under the existing contract constraints. The grid is displayed as Attachment II.3.

H. REFINEMENT OF MATRIX WITH CONSIDERATION FOR SIZE OF WORKER POPULATION AND RELATIONSHIP BETWEEN MEASUREMENT AND HAZARD

In order to focus on the occupational groups with the most potential for work safety hazards related to metric conversion, the size of the worker population was considered. Those occupations with more than .1% of the workforce were retained. The remaining 31 occupations were presented to the Advisory Committee members, who were asked to consider the relationship between the hazard and the measurement sensitivity. The Advisory Committee agreed that the establishment of that relationship was essential.

To facilitate this activity, the Advisors worked independently to analyze the tasks and hazards and to identify measurement relationships. They used the grid described in Part G above. The Advisors were asked to comment on the measurement relationship and level of decisionmaking within the tasks.

The Advisory Committee worksheets (grids) were then analyzed to identify occupations that were considered by a majority of the Advisors to have a measurement relationship to known hazards; then, in cases where measurement was related to worker decisionmaking, the occupation was considered for further study.

At this point, the Advisors were also asked to bring to the attention of the research team any jobs that did not surface in the statistics but merited study. Two occupations were added to the study as a result of this request: crane operators and chemical processing workers.

Crane operators have major safety problems; their job tasks are especially sensitive to measurement; and they can affect public safety.

Chemical processing workers are a difficult group to identify because the classification is viewed as an industry grouping employing many occupational titles. Their job tasks are, however, very sensitive to measurement and highly hazardous.

A third occupation was also included at the request of the Metric Board and with the concurrence of the Advisory Committee. This occupation -- airline pilots -- does not appear to be hazardous; however, it is highly measurement sensitive and often requires pilots to interface with the predominantly metric-oriented international workforce, raising public safety concerns.

The following list represents the occupations that were selected by the Advisory Committee as being most appropriate for this study.

- Millwrights
- Structural Metal Workers
- Plumbers and Pipefitters
- Welders and Cutters
- Auto and Truck Mechanics
- Forklift and Towmotor Operators
- Garage and Gas Station Operators
- Electricians
- Airline Pilots
- Chemical Processing Workers
- Construction Crane Operators

I. UNIVERSITY FORUMS

Various data gathering methods were considered, including mail surveys, telephone surveys, and field visits to various companies. The mail

and telephone survey methods were eliminated because it was felt that there were aspects of the study that could not be easily explained in brief conversations or in a letter. In addition, although the research staff had gathered data through plant site visits in the "Worker Tool and Training Study", similar site visits were not considered to be a cost effective data gathering methodology for this study.

In the previous study, input was required from workers, managers, trainers, and union representatives who had experienced a hard metric conversion. In a typical site visit, all of these personnel were available. For the current study, which examines potential safety hazards, input was required from Industrial Hygienists and Safety Engineers, because workers, managers, and trainers did not necessarily experience a metric conversion. Therefore, the hypothesis could not easily be tested with the more diverse group of employers and employees.

The limited forum was selected as the best means of collecting data because, in one trip, the study team could get information from experts who represented all of the selected occupations, as well as from the academic community, labor, government, and private industry. The forum participants were briefed in advance about the purpose of the study. By limiting the forums to invited guests, more time could be spent on the issues and less time on orientation.

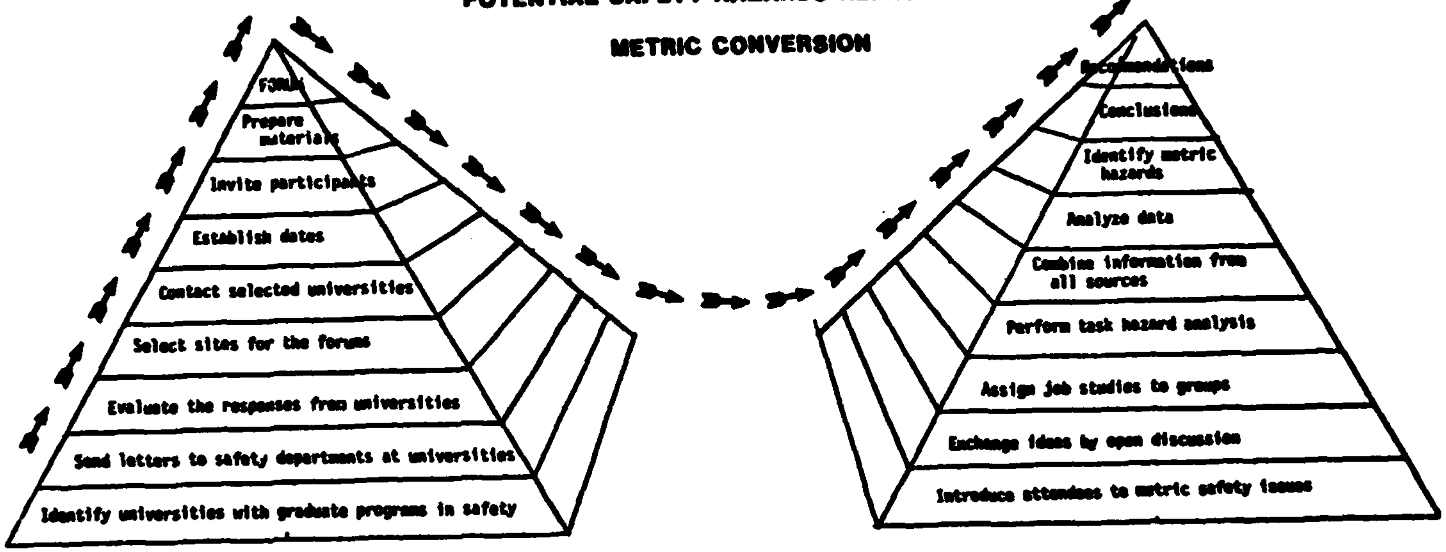
In order to ensure that the forum participants were qualified to address the issues relating to the selected occupations, universities were asked to sponsor the meetings and to select the participants. Central Missouri State University's Safety Center and the University of Southern California's Institute of Safety and Systems Management complied with our requests. These two schools were selected on the basis of their excellent graduate programs in Industrial Safety and the enthusiasm of the faculty about the project. In addition, the geographic spread assured better input and data for the study.

The forum mechanism is shown in Figure 3.

Attachment II.11 is a sample of the letter that was sent to potential forum participants. Appendix I of this report is a copy of the materials that were provided to the participants prior to the forums. Attachments II.11.1 and II.11.2 are the rosters of the two forum participants. Attachment II.11.3 shows the Forum Plan.

FIGURE 3

AN OPERATIVE MODEL OF AN ANALYTICAL APPROACH TO
POTENTIAL SAFETY HAZARDS RELATED TO
METRIC CONVERSION



ATTACHMENT II.1

PROJECT SCHEDULE

September 2, 1981	Planning meeting
September 9, 1981	Notes on planning meeting submitted
September 14, 1981	Advisory Committee formed
October 19, 1981	Draft project plan submitted to Advisory Committee
October 26, 1981	Advisory Committee meets
November 2, 1981	Draft Project Plan submitted to USMB
November 5, 1981	Draft Project Plan approved or revised by USMB
November 1 - January 31, 1982	Data collection through forums described in Project Plan
February 1, 1982	Status Report
February 28, 1982	Submit Preliminary Draft Final Report
March 26, 1982	Submit Draft Final Report
April 3, 1982	Review with U.S. Metric Board
May 1, 1982	Submit Final Report and Executive Summary

ATTACHMENT II.2

ADVISORY COMMITTEE MEMBERS

Mr. Harold Goetz
Director of Safety
Johnson Motors
Waukegan, Illinois 60085

Dr. James Johnson
Department of Health and
Human Services
8120 Hillcrest Drive
Manassas, Virginia 22111

Mr. Darrell Spencer
Industrial Hygienist
AFL-CIO
1300 Connecticut Avenue
Washington, D.C. 20036

Mr. Raymond Seifert
Insurance Engineering and Audit
United States Fidelity and Guarantee
100 Light Street
Baltimore, Maryland 21203

Robert Semonisck, PhD.
Department of Industrial Safety
Humphrey Building, Room 305C
Central Missouri State University
Warrensburg, Missouri 64093

ATTACHMENT II.3

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY

The occupations shown below are based on injury and illnesses indexes and are for the private sector. Occupations listed have injury and illnesses indexes above the average for all occupations for an industry division. Data sources include: Exhibit B-1 of Effects of Metric Change on Workers Tools and Training, July 15, 1981, prepared by Middlesex Research Center, Inc.; U.S. Department of Labor, Bureau of Labor Statistics, Supplementary Data System, July 1981; Accident Facts, 1980 Edition, National Safety Council, and Page 27 of Accident Facts, 1979 Edition; Occupational Injuries & Illnesses in 1979 - Summary, U.S. Department of Labor, Bureau of Labor Statistics, July 1981; Occupational Injuries and Illnesses in the United States by Industry 1978, U.S. Department of Labor, Bureau of Labor Statistics, August 1980; and Dictionary of Occupational Titles (DOT).

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Millwrights				
Glaziers				
Sheetmetal workers				
Structural metal craft				
Plumbers & Pipefitters				
Carpenters & Appr.				
Asbestos & Insul. workers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 2)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Truck drivers				
Laborers (except farm)				
Mine operators, nec.				
Welders & Cutters				
Vehicle & Equip. cleaners				
Mechanics & Repairmen (Auto, etc.)				
Molders, metal				
Assemblers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 3)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Grindling Machine operators				
Forklift, towmotor operators				
Freight, materials handlers				
Warehouse laborers				
Cleaning service workers				
Stock clerk & Store keepers				
Packers, Wrappers				
Delivery & Route Drivers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 4)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Garbage collectors				
Machinists & appr.				
Garage workers, gas station attendants				
Meat cutters, Butchers				
Stock handlers				
Painters, Constr., Maintenance				
Transp. Equip. operators				
Electricians & appr.				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 5)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Laundry, dry cleaning				
Nursing aids, orderlies, attendants				
Vehicle & equipment handlers				
Food service workers				

RECOMMENDED OCCUPATIONAL AREAS FOR STUDY*

502	Melting, pouring, casting, and related occupations
600	Machinists and related occupations
601	Toolmakers and related occupations
616	Fabricating machine occupations
620	Motorized vehicle and engineering equipment mechanics and repairers
621	Aircraft mechanics and repairers
622	Rail equipment mechanics and repairers
625	Engine, power transmission, and related mechanics
633	Business and commercial machine repairers
771	Stone cutters and carvers
810	Arc welders and cutters
820	Occupations in assembly, installation, and repair of generators, motors, accessories, and related powerplant equipment
821	Occupations in assembly, installation, and repair of transmisssion and distribution lines and circuits
822	Occupations in assembly, installation, and repair of wire communication, detection, and signaling equipment
827	Occupations in assembly, installation, and repair of large household appliances and similar commercial and industrial equipment
860	Carpenters and related occupations
861	Brick and stone masons and tile setters
862	Plumbers, gas fitters, steam fitters, and related occupations
899	Miscellaneous structural work occupations
953	Occupations in production and distribution of gas

* "The Effects of Metric Conversion and Dimensional Sensitive Occupations", 1980.

INITIAL STRUCTURE FOR PRIORITIZING OCCUPATIONS

		OCCUPATIONAL AREAS					
FACTORS	WEIGHT	GLAZIER	PLUMBER	CARPENTER	--	PACKERS	ELEC.
1. Hazard Statistical Data							
2. Worker Population							
3. SI Unit Complexity							
4. Extent of Dual Usage Required							
5. Degree of Job/Task Judgement							
6. Availability of Job/Task & Hazard Analys. Data							
7. *							
8. *							

*Other factors to be added later in this study.

DATA SOURCES

ARCO; Los Angeles, California

Armco, Inc.; Kansas City, Missouri

Bendix Corporation; Kansas City, Missouri

Burns and McDonnell; Kansas City, Missouri

Canadian Department of Labor

Canadian Safety Council

Central Missouri State University

Department of Industrial Safety Hygiene

Department of Construction Technology

Florida Steel Corporation; Tampa, Florida

Gas Service Company; Kansas City, Missouri

Hughes Aircraft; Los Angeles, California

Jim Walter Corporation; Tampa, Florida

Johnson Motors; Milwaukee, Wisconsin

Lockheed; Los Angeles, California

Maryland Casualty Corporation; Tampa, Florida

Metric Commission of Canada

Mobay Chemical Corporation; Kansas City, Missouri

National Safety Council; Los Angeles, California

Northrop Corporation

TRW Systems; Los Angeles, California

U.S. Department of Health and Human Services

National Institute of Occupational Safety and Health

U.S. Department of Labor

Bureau of Labor Statistics

Occupational Safety & Health Administration

U.S. Department of Transportation

Federal Aviation Administration

United States Fidelity and Guarantee Company

University of Southern California

Institute of Safety and Systems Management

Workmen's Compensation Board

New York State

COLLEGE AND UNIVERSITY CONTACTS

Auburn University - Auburn, AL
M.S. - Industrial Engineering, Occupational Safety and Health option

Central Missouri State University - Warrensburg, MO
M.S. - Industrial Safety, Agricultural Safety, Aviation Safety, Transportation Safety or Industrial Safety

Central State University - Edmond, OK
M.B.A. - Occupational Safety and Health option

Colorado State University - Fort Collins, CO
M.S. - Safety

Columbia University - New York, NY
M.P.H. - Occupational Health Management option

Drexel University - Philadelphia, PA
MS.S., Ph.D. - Environmental Engineering and Science

Georgia Institute of Technology - Atlanta, GA
M.S. - Industrial Engineering, Safety Engineering option

Harvard University - Boston, MA
M.S. - Industrial Hygiene

Illinois State University - Normal, IL
M.S. - Industrial Technology, Occupational Safety option

New Jersey Institute of Technology - Newark, NJ
M.S. - Industrial Engineering and Management Engineering, Health and Safety Engineering specialization

New York University - New York, NY
M.S., Ph.D. - Industrial Safety; Environmental Health, Industrial Hygiene option

North Carolina State University - Raleigh, NC
M.S., Ph.D. - System Safety Engineering

Northern Illinois University - DeKalb, IL
M.S. - Safety

Northwestern University - Evanston, IL
M.S., Ph.D. - Environmental Health Engineering, Industrial Hygiene, or Health Physics option

Texas A&M University - College Station, TX
M.S. - Industrial Safety or Industrial Hygiene; M.E. - Industrial Engineering with Safety Engineering specialty; Ph.D. - Industrial Engineering with emphasis on Industrial Hygiene & Safety Engineering

University of Arizona - Tucson, AZ
M.S. - Safety Management

University of California - Berkeley, CA
M.S., Ph.D. - Industrial Hygiene

University of Cincinnati - Cincinnati, OH
M.S., Ph.D. - Industrial Hygiene

University of Michigan - Ann Arbor, MI
M.S. - Occupational Safety and Health Engineering or Industrial Hygiene

University of Minnesota - Minneapolis, MN
M.S., Ph.D. - Environmental Health, Occupational Health option

University of Minnesota - Duluth, MN
M.S. - Industrial Safety

University of North Carolina - Chapel Hill, NC
M.S., Ph.D. - Occupational Health

University of Oklahoma - Oklahoma City, OK
M.S., Ph.D., M.P.H, or Dr. P.H. - Occupational Health

University of Pittsburgh - Pittsburgh, PA
M.S. - Industrial Hygiene or Environmental Acoustics

University of Southern California - Los Angeles, CA
M.S. - Safety

University of Tennessee - Knoxville, TN
M.P.H. - Environmental - Occupational Safety and Health option

University of Washington - Seattle, WA
M.P.H. Environmental Health - Industrial Health - Safety option

University of Wisconsin - Madison, WI
M.S., Ed.D. - Occupational Safety and Health

Wayne State University - Detroit, MI
M.S. - Industrial Engineering, Occupational Safety and Health option or Industrial Hygiene

West Virginia University - Morgantown, WV
M.S. - Safety Management

ATTACHMENT II.8

ORGANIZED LABOR CONTACTS

International Association of Machinists and Aerospace Workers

International Brotherhood of Electrical Workers

Greater Kansas City Building and Construction Trades Council

Air Line Pilots Association

International Union of Operating Engineers

MOST HAZARDOUS OCCUPATIONS

Millwrights

Glaziers

Sheetmetal workers

Structural metal craft

Plumbers and pipefitters

Carpenters and apprentices

Asbestos and insulation workers

Truck drivers

Laborers (except farm)

Mine operators

Welders and cutters

Vehicle and equipment cleaners

Mechanics and repairmen (auto, etc.)

Molders, metal

Assemblers

Grindling machine operators

Forklift, towmotor operators

Freight, materials handlers

Warehouse laborers

Cleaning service workers

Stock clerk and store keepers

Packers, wrappers

Delivery and route drivers

Garbage collectors

Machinists and apprentices

Garage workers, gas station attendants

Meat cutters, butchers

Stock handlers

Painters, construction, maintenance

Transportation equipment operators

Electricians and apprentices

Laundry, dry cleaning

Nursing aids, orderlies, attendants

Vehicle and equipment handlers

Food service workers

Estimate of the Number of Employees Whose Jobs
Are Sensitive to Measurement:

For Two-Digit DOT Occupational Titles With Over 500,000 Employees Impacted
Based on 1976 Employment Data

Estimated Number of Employees Impacted	DOT Code	Occupational Title
4,636,916	18	Managers and Officials
3,692,272	07	Medicine and Health
3,164,249	62/63	Mechanics and Machinery Repairers
3,119,065	86	Construction
2,387,359	00/01	Architecture, Engineering and Surveying
2,343,369	31	Food and Beverage Preparation
1,565,775	91	Transportation
1,516,295	09	Education
1,050,330	21	Computing and Accounting
1,038,481	92	Packaging and Materials Handling
1,032,799	90	Motor Freight Occupations
994,423	89	Structural Work Occupations
910,966	60	Metal Machining
826,832	24	Miscellaneous Clerical
822,894	16	Administrative Specializations

(continued)

Attachment II.10 - continued

Estimated Number of Employees Impacted	DOT Code	Occupational Title
807,092	42	Agricultural and Related Occupations
704,095	22	Production and Stock Clerk and Related Occupations
612,747	25	Sales Occupations, Services
571,842	82	Electrical Assembling, Installing, and Repair

Source: "The Effects of Metric Conversion on Measurement and Dimensional Sensitive Occupations" Final Report - Volume I - December 1980

ATTACHMENT II.11

MRC
MIDDLESEX RESEARCH CENTER, INC.
3413½ M STREET, N.W. • WASHINGTON, D.C. 20007 • (202) 333-1925

8 December 1981

Mr. John Bash
Safety Manager
Mobay Chemical Corporation
P.O. Box 4913
Kansas City, Missouri 64120

Dear Mr. Bash:

We are pleased that you will participate in our Metric Safety Hazards Forum on December 18, 1981, in Kansas City. This forum is being co-sponsored by the Middlesex Research Center, Inc. and Central Missouri State Safety Center in order to gather data for the United States Metric Board on potential safety hazards occurring as a result of industrial metric conversion.

In order to brief you on the impetus of this study, I have assembled some materials, including the study background, a summary of the first Advisory Panel meeting, and the Project Plan. These should give you an overview of the issues and an introduction to our approach.

For the forum itself, we ask that you be prepared to address the hazards in the tasks of one or more of the occupations being studied. The final list of occupations is attached to this letter and was derived from the steps described in the Project Plan. In addition, we ask you to consider the following questions related to that job.

- To what extent is measurement involved?
- What measurements are used?
- Are the measurements communicated between workers verbally or are they recorded?
- Is the worker required to make decisions based on measurement; i.e., open a valve to a certain pressure?

In addition to obtaining your input on the hazards issue, we hope to get recommendations for preventive measures. So far, we have learned that the best prevention is training, but we need to know from you how much training is necessary, what kind of training is most appropriate, and if there are any other prevention recommendations.

I hope this letter and the enclosures have adequately presented our task and approach. If not, or if you have any questions or suggestions, please give me a call here at MRC. The research team, including Dr. Robert Semonisck of CMSU, Joe Pokorney - Vice President of MRC, Dorothy Leedom - Research Associate of MRC, and I look forward to meeting you on the 18th of December at 9:00 a.m.

Sincerely yours,

MIDDLESEX RESEARCH CENTER, INC.

Judith LeFande
Senior Associate

Enclosures

cc: Ed McEvoy, USMB
Dr. Robert Baldwin, CMSU
Dr. Robert Semonisck, CMSU

ATTACHMENT II.11.1

CENTRAL MISSOURI STATE UNIVERSITY FORUM PARTICIPANTS

December 18, 1981

Mr. John Bash
Safety Manager
Mobay Chemical Corporation
P.O. Box 4913
Kansas City, Missouri 64120

Mr. Dennis Burks
Safety and Health Trainer
Greater Kansas City Building and
Construction Trades Council
6301 Rockhill Road
Suite 303C
Kansas City, Missouri 64131

Mr. Robert W. Chaney
Associate Safety Engineer
Armco, Inc.
7000 Roberts Road
Kansas City, Missouri 64125

Mr. Tim Batz
Burns and McDonnell
4600 East 63rd Street
Kansas City, Missouri 64141

Mr. Dale Daniel
Senior Safety Engineer
Bendix Corporation
2000 East Banister Road
Kansas City, Missouri 64141

Dr. Jack Landers
Director
Department of Construction Technology
Central Missouri State University
Warrensburg, Missouri 64093

Mr. Dan Morton
Safety Director
Gas Service Company
2460 Pershing Road
Kansas City, Missouri 64108

Robert Semonisck, PhD.
Department of Industrial Safety
Hygiene
Humphrey Building, Room 305C
Central Missouri State University
Warrensburg, Missouri 64093

ATTACHMENT II.11.2

UNIVERSITY OF SOUTHERN CALIFORNIA FORUM PARTICIPANTS

February 2, 1982

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3760 South McClintock Avenue
#101-A
Los Angeles, CA 90007
(Graduate Student / Venezuela)

O'Hara, William
Corporate Director of Product Assurance
Hughes Aircraft Company
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Mail Station 566
P.O. Box 92426
Los Angeles, CA 90009

Mitchell, Charles
Vice President, Loss Control
Western Employers Insurance Company
515 North Cabrillo Park Drive
Santa Ana, CA 92702

Spielman, Howard
President
Health Science Associates
10941 Bloomfield
Suite C
Los Alamitos, CA 90720

Decker, Larry
Safety and Health Consultant
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(Mail Code AP460)
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Los Angeles, CA 90071

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Hawthorne, CA 90250

Kellehar, Richard G.
Environmental Health Manager
Health and Safety Department
TRW Defense and Space Systems Group
Mail Code R4/2073
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Rendondo Beach, CA 90278

Donnelly, William
Manager, Occupational Safety and Health
Lockheed California Company
P.O. Box 551
Burbank, CA 91520

Susser, Lester
Human Factors Scientist
3319 Lowry Road
Los Angeles, CA 90027
(Lockheed California Company)

PLAN FOR METRIC SAFETY FORUMS

1. Criteria for participation.

   Participants should have:

   - Knowledge of the safety issues for the occupations to be studied
   - Active safety training programs
   - Interest or awareness of metric conversion issues.

2. Preparation for participants.

   Each participant will be provided with:

   - A letter of explanation for the forum
   - Background information for the study
   - The study plan
   - A list of questions to be raised at the forum.

3. Forum Structure.

   - Ideally forums will be sponsored by university departments with safety programs by professional associations.
   - Meetings will be limited to researchers, sponsors, and four to six forum participants.
   - Meetings will address each issue in a question and answer format.
   - Forums will last no longer than one day and will be scheduled at a time mutually agreeable to researchers, sponsors, and participants.

4. Forum Content.

   The content of the forum will follow the outline listed below.

METRIC SAFETY HAZARDS STUDY

One-Day Forum Tentative Outline

1. Welcome and Study Background

2. Review of Occupational Areas and Population/Hazard Data

3. Discussion of Job/Task Analysis and Job Safety Analysis Data for Selected Occupations

4. Discussion of Metric Conversion Issues in Job/Tasks for Selected Occupations

5. Identification of Specific Potential Safety Hazards

6. Consideration of Preventive Mechanisms for Metric Safety Hazards and Associated Costs of Those Mechanisms

7. Identification of Associated Public Hazards

III. DATA ANALYSIS

This section of the report presents the results of the data gathered during the study. The analysis is presented in a sequence that generally follows the methodology steps outlined in Section II. Part F, Metric Related Job Hazards, summarizes the analysis and serves as the foundation for the conclusions and recommendations presented in Sections IV and V.

A. ANALYSIS OF SOURCE DATA

As indicated previously, a variety of data sources were used in an attempt to capitalize on existing relevant job hazard data. The intent was to identify metric measurement related hazards as an extension of the existing data. This objective was only partially satisfied due to a dearth of information regarding job hazards associated with metric change and the limitations of the methods used to present occupational data in this country.

1. Technical Journals

A review of the technical journals published by health, safety, and metric related associations identified only a few articles that discussed the issue of metric change and occupational safety. In general, these articles tended to be somewhat superficial and speculative. A thorough review of these materials did not identify any specific examples of increased hazards associated with metric change. Most of these articles were written in 1971-1975, when there was a high level of interest in metric change in the United States but very little practical experience with such change.

2. Occupational Injury Data

The Bureau of Labor Statistics and the Occupational Safety and Health Administration within the U.S. Department of Labor, as well as the National Safety Council and the National Institute of Occupational Safety and Health, are all involved in the publication of various statistics and data related to occupational hazards and accidents. An extensive review of all of these existing sources indicated that most analysis focuses on the sources of occupational injuries, types of injuries workers incur, amounts of compensation payment, and various other data that describe the circumstances associated with the injury and the nature of the injury itself. Only OSHA collects data regarding the cause of injuries; and since OSHA's statistics are very limited, they were not considered in the study.

The only other sources of information addressing the cause of accidents are data collected by individual corporations in pursuit of internal safety programs and data collected by insurance companies or others involved in workmen's compensation programs. Both private industry and insurance companies consider this data to be sensitive and confidential. None of these data are available to the public and, therefore, could not be used as a basis for analysis in this study.

3. Hazard Analysis Data

The safety community -- which includes safety professionals in industry, safety consultants, and Federal agencies such as the Occupational Safety and Health Administration (OSHA) -- has developed techniques to analyze job hazards. These techniques are typically used in preventive analysis that focuses on the tasks performed or procedures involved in the individual job. The analytical technique consists of documenting the specific steps associated with a procedure or job and identifying each of the hazards that might result in performing those steps. Once the job hazard analysis has been completed, preventive measures are taken to deal with the potential hazards—so as to reduce the injuries associated with a particular job.

In most cases, the preventive steps include training, procedure modification, or redesign of the job tasks. Although the techniques for performing job hazard analysis have been documented and discussed by many organizations and individuals, the results of such studies are not generally available. Typically, these studies are performed by individual companies as part of their ongoing safety programs. Once again, much of this data is considered sensitive and is not available to the public at large.

4. National Industry - Occupation Employment Matrix

For many years, the Bureau of Labor Statistics (BLS) within the U.S. Department of Labor has published statistical data reflecting industry employment. Some of this information uses as its primary source the most recent census data, which is collected every 10 years by the Census Bureau. Other reports have been prepared using a BLS survey entitled, "The Office Employment Statistics" (OES instrument). This data collection method serves industry in a variety of ways, one of them dealing with employment. One of the newer BLS publications is the "National Industry Occupation and Employment Matrix", which is a table depicting the occupational employment structure of U.S. industries. This particular document divides U.S. employment into 425 occupations and 260 industries. The matrices are presented in two different ways: first, distribution of industry employment by occupation; and second, distribution of occupation employment by industry. Data are provided for 1970, 1978, and projections for 1990. This occupational matrix (using the data for 1978) provided the primary basis for determining the number of individuals employed in selected occupations

by each industry to be studied. A summary from this matrix indicating the distribution of selected occupations is shown as Attachment III.1.

5. Industry Metric Experience

Since this study was to focus specifically on the occupational hazards impact associated with changes to metric measurement, a review of all metric conversion activities was performed. This review included analysis of American National Metric Council materials, U.S. Metric Board materials, Middlesex Research Center's library on metric conversion activities, resources from the United States Metric Association, and other sources regarding metric experiences within the United States. As a result of this analysis, the consulting team assembled a representative picture of the current experiences with metric change in this country. Throughout this analysis, the research was unable to identify any particular industry experience that addressed the issue of job hazards associated with metric change. While many individuals expressed interest in the topic and could relate hypothetical situations where job hazards might occur, no specific data were available.

B. HAZARDOUS OCCUPATION DATA

Hazardous occupation statistics are collected and reported by a variety of sources. Among those that were reviewed in the course of the study were data from the National Safety Council, the Bureau of Labor Statistics, the Occupational Safety and Health Administration, selected state workmen's compensation agencies, and the Monthly Labor Review. Typically, all of these organizations report a variety of statistics regarding occupational injuries. In almost every incident, these data report the type of injury sustained, the part of the body that was injured, the contributing source (e.g., motor vehicle, working surface, etc.), and in some cases the amount of unemployment compensation or the cost of being away from the job.

None of these data sources routinely report information regarding the cause of the accident or injury, and most of the data is reported by industry, not by occupation. However, an analysis of these data, which is summarized in Attachments III.2, III.3, and III.4, indicate the following: overall, the most common occurrence of injury results in a sprain or strain of some part of the body, followed by cuts or lacerations, contusions, and bruises. Similarly, the part of the body that most often sustains injury is the back, followed by fingers and thumbs, legs, eyes, etc. If one examines the major categories of injury occurrence, it appears that overexertion caused by trying to lift heavy objects is the most significant cause of worker injury. In examining the potential opportunities for increased exposure to back strain associated with metric change, only one possible situation appears plausible. That would be the potential increase for injuries resulting from changes in standardized container sizes for bagged products, such as chemicals or cement, or other containers, such as

five-gallon pails of joint compound or adhesives. This increase would only apply if the standards are changed to substantially larger or heavier standard sizes. A reduction in hazards might well result from smaller or lighter standard sizes.

An analysis of the source of the injuries (Attachment III.5) indicates that two primary sources are metal items and working surfaces, which include floors, stairways, and other surfaces that individuals slip or fall onto; followed by boxes, barrels, and other containers; and then vehicles. Most of these categories appear to be relatively insensitive to the measurement units being used. Those accidents involving working surfaces -- floors, stairways, and walkways -- do not appear to be impacted by the change to metric measurement. Similarly, an incident involving an individual being struck by an item would appear to be relatively unchanged by a change in metric units. However, in those cases where bodily motion and machines are involved, there might well be specific incidences where the change to metric measurement involves judgment and increases the worker's exposure to occupational hazard.

Analysis of the occupational injuries data suggested examination of three distinct categories of injuries:

- Injuries to the individual worker caused by and sustained by his own actions or other actions associated with his work environment.

- Injuries sustained by co-workers as a result of another individual at the job site inappropriately taking actions or otherwise miscalculating measurement data. An example of this would be an individual worker dropping an item on another worker, or causing a fire or explosion that would injure co-workers.

- A third category involves those injuries to the public at large as a result of an occupational situation. In this case, the worker might, by inappropriately using a crane, cause materials to fall on passers-by in the street; or, in a more extreme case, an airline pilot, due to improper judgment involving measurement units, might jeopardize the safety of his passengers.

It is difficult to focus directly on occupational injuries by type of job, because all of the reporting mechanisms focus on occupational injuries by major industry group. The Bureau of Labor Statistics, in Bulletin 207A, publishes an annual tabulation of occupational injuries and illnesses by industry. Using the 1978 data, which is shown in Attachment III.6 in abbreviated form, those industries with the highest number of occupational injuries and illnesses can be reviewed. It is only by linking this occupational injury data through the National Industry Occupation Employment Matrix that research begins to relate those areas of high employment and measurement sensitive jobs with workers who have substantially higher occupational hazards than average.

The Bureau of Labor Statistics has begun to collect occupational injury data from 25 states that relates occupational injuries to individual occupational categories. These data are collected from the states' workmen's compensation programs and can be provided on request through a computerized data management system operated by the Bureau of Labor Statistics.

C. THE METRIC HAZARDS OCCUPATION MATRIX

In Section II of this report, the Metric Hazards Occupation Matrix was described in general as a methodology for linking occupations with high employment, above average injury and illness rates, and higher than average sensitivity to metric measurement. Through research, discussions with the Advisory Committee, and discussions at the two university forums, the original matrix was condensed so as to focus on the 12 occupations that satisfied these criteria or were of specific interest to the U.S. Metric Board. Attachment III.7 provides a summary of those occupations, indicating the percentage of the total workforce employed and the extent to which the occupations are hazardous, measurement sensitive, or afford substantial public safety hazards.

Attachment III.8 shows these same occupations and indicates measures of occupational illnesses or injuries used in this study. Two primary sources of such data were used, both acquired from the Bureau of Labor Statistics. In each case, the Bureau of Labor Statistics was provided with a listing of the major occupational areas that were of interest to the study. This included the initial list of 32 occupations, as well as the 12 occupations to be analyzed. Through their computerized data management system, BLS was able to prepare two separate listings identifying injury and illness incidence rates by occupation. One set of data was from 25 states, and the second set was from 14 states. Each report was based on 1978 data collected from the states' workmen's compensation programs. The hazard ratio index computed by BLS as "The Percent of Injuries Divided by the Percent of Employment" was used as a primary indicator for verification of those occupations considered to be most hazardous.

In an effort to identify the major industries that employ workers in those occupations that are both hazardous and measurement sensitive, the occupations of interest were analyzed using the Bureau of Labor Statistics' Industry Occupation Matrix. A summary of this information is provided in Attachment III.9, indicating the major areas of employment for the selected occupations and showing a summary of the injury incidence rate along the bottom of the chart. Using this approach, major occurrences of industry employment for the occupations that were both hazardous and measurement sensitive were identified. This information was used to ensure that representative safety professionals from those industries were participants in the university forums.

As a result of the analysis of the metric hazards occupation matrix, specific industry and occupation combinations were identified for which

job hazard analysis data were to be developed. The primary focus of this analysis was to identify selected occupational areas for which job hazard analysis information would be most valuable in identifying potential safety hazards resulting from metric change.

D. JOB HAZARD ANALYSIS

In conducting a job hazard analysis, the initial step is to break down a specific job into individualized tasks. This task breakdown is used to identify each particular action taken by an employee in performing a particular job. Such a task might be reaching into a metal box to pick up a part, inserting a drill bit into a drill press, or reading a gauge to determine a particular temperature or pressure in a chemical process. Therefore, each job hazard analysis begins with a detailed listing of the job tasks in the sequence that they are to be performed. Normally this is conducted through observation of actual employees while they are performing their jobs.

Following identification of the job tasks, each job task is analyzed to determine the potential hazards associated with that task. Such hazards might include inserting a hand into a moving part, inserting fingers or other extremities close to cutting tools, strain related to lifting objects that are heavier than can safely be lifted, dropping parts or other materials onto individuals, etc.

Once the safety hazards have been identified, recommendations for safe procedures and protection of the worker are developed so as to minimize his exposure to each hazard. Such recommendations might include: installation of a guard to prevent hands from being inserted into machinery, provision of safety gloves and safety eyeglasses, changes in procedures to ensure that certain steps are followed in the proper sequence, or a recommendation that only certain sizes or a standard quality of product be used in a particular process.

Since the research phase of this study was unable to identify sources of job hazard analysis related to metric measurement or major published data on job hazard analyses, alternative approaches had to be developed to generate this information. The resources available to the project prevented the conduct of job hazard analyses for a substantial number of occupations involved in the study. However, it was determined after meeting with the Advisory Committee that, in the process of conducting the university forums, job hazard analysis data for the occupations selected for the study could be collected from a group of knowledgeable experts in the field. Once this raw data was collected from the participants, the research staff refined and clarified the information. The results of these job hazard analyses are provided in Attachment III.10.

The job hazard worksheets that are included in Attachment III.10 are representative of the types of hazards that might be associated with a change to metric measurement units. They are not, however, all inclusive

for those occupations discussed, since the time and costs associated with conducting a job hazard analysis for every potential measurement-related hazard would have been prohibitive. However, based upon the analyses of the occupations, injuries associated with these occupations, and the measurement sensitivity associated with these jobs, the data represent the most likely potential for metric related hazards.

E. MEASUREMENT CHANGE IN THE WORKFORCE

Based upon the results of the previous studies conducted by Middlesex Research Center, meetings with the Advisory Committee, and the results of the two university forums, the impact of measurement change on occupations was analyzed. This analysis was conducted in the light of considerable industry experience with continually introducing new technologies in the workplace. Most new technology, such as laser measurement devices, has substantial potential impact on occupational injuries. One of the more consistent attitudes among those in the safety profession was that the major role of individual safety professionals and companies with safety programs is to continually review new processes and new technology so as to reduce the hazard associated with that technology. Thus, the introduction of metric measurement is viewed by many individuals as just another routine change in operational procedures.

Typically, with the introduction of a new technology -- for example, lasers -- the industries that are about to utilize the technology (and the industries' safety professionals) focus their efforts on determining potential safety hazards associated with that technology and the appropriate procedures and protective actions to be taken to ensure a minimum exposure to such hazards by the employee. Most of the safety professionals who were interviewed for this study viewed metric change in a similar fashion. The one caveat in this particular scenario is that, most often, industries or corporations considering the implementation of metric measurement may not involve their safety professionals in the planning process.

In discussions with safety professionals about the nature of job hazards related to changes in measurement systems, it became clear that certain conditions must exist before the safety professional will acknowledge that a potential hazard may exist. These conditions are as follows:

- Judgment - If a job hazard is to be associated with the change in measurement systems, then the worker must be required, in the course of conducting a particular task, to exercise judgment in using measurement units; that is, he must be reading the actual units off a dial, calculating actual data, or converting from customary to metric. In those cases where judgment has been removed from a specific task (that is, observing a dial to determine if a needle is in the red zone or not in the red zone, as opposed to reading the actual value), the likelihood of any substantial hazard occurring as a result of measurement change will be nil.

- Communications - In many occupational situations, two workers are communicating with each other; most often, verbally. In some cases, they are near enough in proximity so as to just speak in a normal voice. In other cases, they are using CB radios or other telecommunication devices. In each case, when a communication element is present, the chance of misinterpreting particular numbers is increased. Thus, if one part of a two-person team is reading temperature in degrees Celsius when the recipient of this data thinks he is receiving numbers in degrees Fahrenheit, there exists an opportunity for confusion and, thus, error. Whenever communication of measurement values or measurement data exists between two or more workers, the potential for hazard increases; and, thus, the potential for hazards associated with metric change would also appear to increase.

- Conditioned responses - In a number of occupations a worker must respond to an emergency situation and typically does this with a conditioned response based on experiential data developed over many years in the occupation. Such occupations would include airline pilots, operators of chemical processing plants, truck drivers, and many other occupations. In these situations, the worker is required to quickly make a judgment without taking time to analyze whether he is using metric measurement or customary measurement, and often without the benefit of accurate measurement information. Thus, when a worker must make an emergency judgment in a metric unit-oriented situation, but all of his experiential data are based on customary units, the potential for judgmental errors leading to a safety hazard could increase.

F. METRIC RELATED JOB HAZARDS

After analyzing all of the safety hazard information and reviewing the job hazard worksheets, it was concluded that the results could best be summarized by considering the occupational areas in three major groups. These groups are Craftsmen, Operatives, and Airline Pilots.

1. Craftsmen

One major group of occupations that was studied included a variety of skilled craftsmen in substantially different occupations, most of which are in the areas of manufacturing and construction. These occupations include the following:

- Millwrights
- Structural metal workers
- Plumbers and Pipefitters
- Welders and Cutters
- Auto and Truck Mechanics
- Electricians.

The common task that was identified in the job hazard analysis worksheets was the situation in which an individual worker must apply judgment in measuring or interpreting measurement data in order to conduct his work. When this judgment is performed in a work environment that requires using either metric or customary units, the potential for a metric-related job hazard exists. Clearly, job situations in which workers use only metric units or only customary units will have less potential for hazards. On the other hand, those job situations where a worker must continually switch back and forth between metric and customary units, or where is he forced to convert from one unit to another, may increase his exposure to hazards. Once again, however, each task must be analyzed to ensure that individual worker judgment is required, or that verbal communication of measurement units is part of the job task before a metric hazard could exist.

2. Operatives

Three of the occupations studied are part of the overall job classifications called Operatives and Kindred Workers. These included the following three categories:

- Forklift and Tow Motor Operators
- Garage and Gas Station Operators
- Construction Crane Operators.

Once again, an analysis of these occupations through the job hazard worksheets led to the definition of certain conditions that might create increased exposure to safety hazards. As with the skilled craftsmen, those situations occurred only when worker judgment or communication of measurement data between one worker and another was required as part of a job.

3. Airline Pilots

Airline pilots are in the occupational category under the heading professional and technical occupations. The dominant mode of employment is in transportation as commercial pilots. Since most of their job tasks require judgmental decisions, as well as the communication of data between themselves, other cockpit crew members, and the air traffic controllers, these aspects of their job are no different whether they are using metric units or customary units. However, the opportunity for confusion does exist. It is in the area of conditioned responses to emergency situations that the airline pilot and his passengers are likely to be exposed to an increased safety hazard as a result of using metric units.

Aviation's concern about safety in metric conversion was well-voiced by the Air Operations Subsection of the ANMC Aerospace Sector Committee's proposal to the U.S. Metric Board in 1981. In that proposal, the Committee requested that human factors research be done in this area.

The list of priorities presented by the Committee is presented below.

- Pilot/cockpit workload and navigation procedures
- Pilot/controller interface
- Dual cockpit presentation/dual instruments vs. total conversion
- Single cockpit displays with self-contained metric/English conversion capability
- Conversion charts, tables, and conversion procedures
- Pilot and other aircrew training procedures and problems (simulators)
- Controller workload and procedures
- Controller training
- Electronic and environmental readouts (analog vs. digital cockpit displays)
- Overall transition and international coordination (mixed metric/English operations, including crew/aircraft/route scheduling during transition)
- Integrating computer conversion of instruments
- Short-term conversion (M-Day) vs. long-term
- Cockpit charting/cartographic problems; e.g., contour lines in metric.

It was not within the scope of this study to do an in-depth analysis of these issues. They were discussed both with Federal Aviation Administration (FAA) flight standards and training representatives and with the Airline Pilots Association. Both groups can provide hypothetical scenarios that involve potential human factor errors on the part of pilots, air traffic controllers, and aircraft mechanics.

As more air traffic control equipment is manufactured in the Soviet bloc nations, and as air traffic controllers are being trained in countries other than the United States (which until recently was the major training ground), there will be increased usage of metric measurement in air space.

The issue as we understand it is not the routine measurement situation, but that in emergencies, when pilots and navigators do not have time to use conversion charts or calculators, there could be serious consequences and threats to public safety.

The following is a partial list of airplane materials and equipment that must be considered in metric conversion plans:

Engine performance indicators
Fuel capacity indicators
Tire pressure
Air frame parts dimensions
Airspeed indicator
Altimeter, barometric and electric
Vertical speed indicator
Distance measuring equipment
Encoding altimeter
Sectional VFR charts, WAC, TCA and approach charts, IFR enroute charts, low and high altitude charts
Approach plate minimums
Weather data, including measuring and dissemination equipment
Radar altimeters
RNAV
INS, including air data displays
Flight handbooks
Pilot operating handbooks
Weight and balance, and performance handbooks
Air traffic control displays and hardware
Aircraft and air traffic control computers (both hardware and software)
VORS and enroute navigational equipment
Air traffic control weather gauges, barometers, altimeters, anemometers, etc.
Flight training curricula, including educational manuals and materials
Supporting aircraft gauges and subsystems, such as fuel flow, oil pressure, manifold pressure, etc.
Global positioning satellite data
LORAN and OMEGA
Airspace separation and ATC capacity revision of FARs 91, 121, 135, etc.
Conversion tables needed for operation in a dual dimension environment
Pilot education/transitional problems, especially during the critical phase.

G. INDUSTRIAL SAFETY PROGRAMS

In discussions with safety professionals at individual corporations, insurance firms engaged in workmen's compensation programs, the Advisory Committee, and the participants at the university forums, the research team tried to identify a generic industrial safety program. The primary focus of an industrial safety program is to minimize the costs of job-related injuries and illnesses. This is generally done through preventive programs

that are constructed in response to job-related hazard data. Typically these data are collected by a specific corporation or its insurance carrier.

In most corporations, the safety professionals are considered advocates for a wide range of safety program activities. However, the opinions of these individuals are not always solicited in advance of new technical-based decisions that a corporation may make. Such decisions might include the development of metric measurement capability or a commitment to move to metric units exclusively.

Safety professionals in industry have developed a fairly uniform methodology for dealing with the introduction of new technologies and for reducing safety hazards that have been documented through data gathering. Once a formal analysis of the problem has been conducted, the safety programs that are developed usually consist of the following elements:

- Safety awareness programs - These programs are used to elevate the general awareness of the worker regarding safety issues that he may encounter in the course of doing his job.

- Training programs - These programs are developed to teach a specific procedure to workers; the procedure is generally related to an individual job task or a series of tasks. These procedures are usually designed to change the current job tasks, or to ensure that a new technology being introduced in the workplace is not misused.

- Procedural changes - These activities result in modifications to the sequence in which work is accomplished or to the method by which work is accomplished, so as to reduce exposure to a specific hazard.

- Equipment modification - This part of the safety program normally includes the addition of safety devices, guards, safety glasses, or other equipment to protect workers from exposure to job-related injuries.

- Equipment standards - In some situations a safety program may involve identification of engineering standards to be used in specifying production equipment, machine tools, or hand tools. The safety experts only get involved in these areas if their studies have shown a direct link between hazard exposure and the quality of a particular product or item.

In the opinion of the safety professionals who were interviewed for this study, any corporation that involved its industrial safety experts in the metric conversion planning activities and in the implementation of training programs would reduce the potential for increased hazard exposure resulting from metric change. The nature of most of the job tasks that can be directly linked to potential increases in hazard exposure resulting from measurement change are those same types of job tasks that are routinely dealt with by safety experts in the course of implementing safety programs.

THE NATIONAL INDUSTRY-OCCUPATION EMPLOYMENT MATRIX OVERVIEW

<-------------- 260 Industry Categories and Sub-Categories -------------->

<-------------- 425 Occupations -------------->

OCCUPATIONS	CATEGORIES AND SUB-CATEGORIES					
	Agriculture	Mining	Manufacturing	Construction	Transportation	Wholesale & Retail
Professional and Technical						
- Airline Pilots	5%	3%	6%	1%	70%	3%
Managers, Officials and Proprietors						
Clerical						
Crafts & Kindred Workers						
- Millwrights	0%	2%	84%	8%	1%	3%
- Structural Metal Workers	0%	1%	25%	70%	1%	1%
- Plumbers & Pipefitters	.4%	1%	18%	62%	6%	5%
- Constr. Crane Operators	1%	5%	61%	17%	6%	7%
- Auto & Truck Mechanics	.4%	2%	25%	5%	9%	31%
- Electricians	.2%	3%	28%	48%	8%	3%
Operatives						
- Forklift & Tow Motor Oper.	.3%	.8%	72%	2%	6%	16%
- Garage & Gas Station Oper.	0%	.1%	.5%	.2%	.8%	93%
Service Workers						
Laborers						

Percent of 1978 Employment Shows in Each Cell

Note: Entries do not total 100% because all entries are not shown.

NATURE OF INJURIES TO WORKERS*

Injury	Percent
1. Sprain - strain	34%
2. Cut - laceration - puncture	17%
3. Contusion - crushing bruise	14%
4. Fracture	8%
5. Scratch - abrasion	4%
6. Burn	3%
7. Hernia	1%
8. Multiple injuries	1%
9. Dislocation	1%
10. Amputation	1%
All others	16%

* Data from 26 states, 1977
Source: Bureau of Labor Statistics

SELECTED PARTS OF BODY INJURED*

Part of Body Affected	Percent
1. Back	20%
2. Fingers	15%
3. Legs	9%
4. Eyes	7%
5. Hand	6%
6. Knee	5%
7. Arm	5%
8. Foot	5%
9. Multiple	5%
10. Ankle	4%
All others	19%

* Data from 26 states, 1977
Source: Bureau of Labor Statistics

SELECTED TYPE OF ACCIDENT*

Accident or Exposure	Percent
1. Over-exertion	22%
2. Struck by object	21%
3. Struck against object	11%
4. Fall on same level	10%
5. Caught in, between or under	8%
6. Bodily reaction	7%
7. Fall from elevation	6%
8. Contact with temperature extremes	3%
9. Motor vehicle accidents	2%
All others	10%

* Data from 26 states, 1977
Source: Bureau of Labor Statistics

SELECTED SOURCES OF INJURY*

Source	Percent
1. Working surfaces	14%
2. Metal items	13%
3. Boxes, barrels, containers	11%
4. Vehicles	7%
5. Bodily motion	7%
6. Machines	7%
7. Hand tools, not powered	6%
8. Wood items	4%
9. Furniture, fixtures	3%
10. Other person	3%
11. Hand tools, powered	2%
All others	23%

* Data from 26 states, 1977
Source: Bureau of Labor Statistics

OCCUPATIONAL INJURY AND ILLNESS INCIDENCE RATES BY INDUSTRY, UNITED STATES, 1977 and 1978

INDUSTRY	SIC Code	Incidence rates per 100 full-time workers							
		Total Cases		Lost Workday Cases		Nonfatal Cases Without Lost Workdays		Lost Workdays	
		1977	1978	1977	1978	1977	1978	1977	1978
Agriculture, forestry, and fishing	N/A*	11.5	11.6	5.1	5.4	6.3	6.2	81.1	80.7
Mining	N/A	10.9	11.5	6.0	6.4	4.9	5.0	128.8	143.2
Construction	N/A	15.5	16.0	5.9	6.4	9.6	9.6	111.5	109.4
Manufacturing	N/A	13.1	13.2	5.1	5.6	8.0	7.6	82.3	84.9
Transportation and public utilities	N/A	9.7	10.1	5.3	5.7	4.3	4.3	95.9	102.3
Wholesale and retail trade	N/A	7.7	7.9	2.9	3.2	4.8	4.7	44.0	44.9
Finance, insurance, and real estate	N/A	2.0	2.1	.8	.8	1.2	1.2	10.4	12.5
Services	N/A	5.5	5.5	2.2	2.4	3.3	3.1	35.4	36.2

* N/A: not available at this level of aggregation.

OCCUPATIONAL INJURY AND ILLNESS INCIDENCE RATES BY INDUSTRY, UNITED STATES, 1977 and 1978

INDUSTRY: MANUFACTURING	SIC Code	Incidence rates per 100 full-time workers							
		Total Cases		Lost Workday Cases		Nonfatal Cases Without Lost Workdays		Lost Workdays	
		1977	1978	1977	1978	1977	1978	1977	1978
Durable Goods									
Lumber and wood products	24	22.3	22.6	10.4	11.1	11.9	11.5	178.0	178.8
Furniture and fixtures	25	17.2	17.5	6.0	6.9	11.2	10.6	92.0	95.9
Stone, clay, and glass products	32	16.9	16.8	6.9	7.8	9.9	9.0	120.4	126.3
Primary metal industries	33	16.2	17.0	6.8	7.5	9.4	9.5	119.4	123.6
Fabricated metal products	34	19.1	19.3	7.2	8.0	11.9	11.3	109.0	112.4
Machinery, except electrical	35	14.0	14.4	4.7	5.4	9.3	9.0	69.9	75.1
Electric and electronic equipment	36	8.6	8.7	3.0	3.3	5.6	5.4	46.7	50.3
Transportation equipment	37	11.8	11.5	5.0	5.1	6.8	6.3	79.3	78.0
Instruments and related products	38	7.0	6.9	2.4	2.6	4.6	4.3	37.4	37.0
Miscellaneous manufacturing industries	39	11.5	11.8	4.0	4.5	7.5	7.3	58.7	66.4

OCCUPATIONAL INJURY AND ILLNESS INCIDENCE RATES BY INDUSTRY, UNITED STATES, 1977 and 1978

INDUSTRY: MANUFACTURING	SIC Code	Incidence rates per 100 full-time workers							
		Total Cases		Lost Workday Cases		Nonfatal Cases Without Lost Workdays		Lost Workdays	
		1977	1978	1977	1978	1977	1978	1977	1978
Nondurable goods									
Food and kindred products	20	19.5	19.4	8.5	8.9	11.0	10.5	130.1	132.2
Tobacco manufactures	21	9.1	8.7	3.8	4.0	5.3	4.6	66.7	58.6
Textile mill products	22	10.2	10.2	2.9	3.4	7.3	6.8	57.4	61.5
Apparel and other textile products	23	6.7	6.5	2.0	2.2	4.7	4.3	31.7	32.4
Paper and allied products	26	13.6	13.5	5.0	5.7	8.5	7.8	101.6	103.3
Printing and publishing	27	6.8	7.0	2.7	2.9	4.1	4.1	41.7	43.8
Chemicals & allied products	28	8.0	7.8	3.1	3.3	4.9	4.5	51.4	50.9
Petroleum and coal products	29	8.1	7.9	3.3	3.4	4.8	4.5	59.2	58.3
Rubber and miscellaneous plastic products	30	16.8	17.1	7.6	8.1	9.1	9.0	118.1	125.5
Leather and leather products	31	11.5	11.7	4.4	4.7	7.1	6.9	68.9	72.5

FINAL SUMMARY OF OCCUPATIONS TO BE STUDIED

FOR METRIC CONVERSION SAFETY HAZARDS

OCCUPATION	HAZARDOUS?	MEASUREMENT SENSITIVE?	% OF TOTAL WORK FORCE	POTENTIAL PUBLIC SAFETY HAZARD?
Millwrights	yes	yes	.1%	no
Structural Metal Workers	yes	yes	.08%	no
Plumbers and Pipefitters	yes	yes	.45%	yes
Mine workers+	yes	N/A	.82%	N/A
Welders & Cutters	yes	yes	.72%	no
Auto and Truck Mechanics	yes	yes	1.09%	no
Forklift and Tow-motor Operators	yes	yes	.39%	no
Garage and Gas Station Operators	yes	yes	.44%	no
Electricians	yes	yes	.63%	yes
Airline Pilots	no	yes	.08%	yes
Construction Crane Operators	yes	yes	.17%	yes
Chemical Processing Workers	yes	yes	Unknown (*)	no

+ Data on mining operations were not readily available from the Mining Safety Administration or other sources.

* Chemical Processing Workers are not reported by occupation.

OCCUPATIONS OF INTEREST SHOWING INJURY AND ILLNESS MEASURES

OCCUPATIONS OF INTEREST	1978 Employment		SOURCE A		SOURCE B
	Thousands	Percent	Hazard Ratio Index	% Injured	# Cases
Millwrights	95	.1%	2.57	.36	2,500
Structural metal workers	78	.08%	3.55	.39	2,600
Plumbers and pipefitters	428	.45%	1.78	.91	6,800
Mine workers	204	.22%	N/A	N/A	4,700
Welders and cutters	679	.72%	2.29	2.11	15,300
Auto and truck mechanics	1025	1.09%	1.64	6.52	13,900
Forklift and towmotor operators	363	.38%	1.81	.94	7,600
Garage and gas station operators	416	.44%	1.22	.73	5,900
Electricians	590	.63%	1.28	.92	6,774
Airline pilots	72	.08%	N/A	N/A	N/A
Construction crane operators	156	.17%	N/A	N/A	1,500
Chemical processing workers	N/A	N/A	N/A	N/A	N/A

Total 1978 Employment was 94,372,600 = 100%*

* Totals do not equal sum of entries because only occupations of interest are shown.

(1) Source A: Bureau of Labor Statistics data from 25 states, 1978.

(2) Source B: Bureau of Labor Statistics data from 14 states, 1978.

(3) Ratio is % injured divided by % employed in the 25 states.

N/A: Data not readily available

INDUSTRIES THAT EMPLOY OCCUPATIONS OF INTEREST SHOWING SIGNIFICANT EMPLOYMENT PERCENTAGES

AND OCCUPATIONAL INJURY INCIDENCE RATES

OCCUPATIONS OF INTEREST	1978 Employment		Manufac-turing	Construc-tion	Transport and Utilities	Wholesale and Retail	Services	Mining
	Thousands	Percent						
Millwrights	95	.1%	84%	8%				
Structural metal workers	78	.08%	25%	70%				
Plumbers and pipefitters	428	.45%	18%	62%	6%	3%		
Mine workers	204	.22%						100%
Welders and cutters	679	.72%	66%	12%	3%	5%	10%	2%
Auto and truck mechanics	1025	1.09%	7%		8%	46%	32%	
Forklift and towmotor operators	363	.38%		72%	6%	16%		
Garage and gas station operators	416	.44%				93%		
Electricians	590	.63K	27%	48%	8%			
Airline Pilots	72	.08%			69%			
Construction crane operators	156	.17%	61%	17%	6%	7%		5%
Chemical Processing workers[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Injury Incidence Rate			13.2	16	10.1	7.9	5.5	11.5

1 Data are not available (N/A) since chemical workers are not reported as an occupation.

JOB HAZARD WORKSHEET

Occupation: Construction Crane Operator

Job Task:

Determine the weight of a load to be lifted by a crane. This is typically done by reading the label on the load, by experiential knowledge of how heavy a particular type of load is, or by estimating procedures. Most estimating procedures are very informal.

Hazard:

If the weight of the load is underestimated, this may result in the selection of improper slings, improper placement of the crane, or use of a crane that is unable to lift such a load. All of these errors can result in hazards such as: (a) dropping the load; (b) tipping over the crane; (c) damage to the crane or other lifting apparatus.

Metric Impact:

Typically, loads are estimated in hundreds of pounds, thousands of pounds, or tons. Thus, a load that would weigh approximately 4,500 pounds might be viewed as 4-1/2 thousand pounds; four thousand five hundred pounds; or a little over two tons. In the metric system, such loads will be labeled in kilograms or metric tons, such as 2,000 kilograms or 2 metric tons.

ATTACHMENT III.10.2

JOB HAZARD WORKSHEET

Occupation: Construction Crane Operator

Job Task:

Determine the boom angle to be used in lifting a given load. The boom angle on many cranes is controlled by the operator, and the closer the boom is to the vertical position, the heavier the load the crane can lift. Setting the boom angle is a function of the crane location, the location of the load to be lifted, and the location of the point at which the load is to be deposited.

Hazard:

Since the angle of the boom is a direct function of the weight to be lifted, an error in judgement on the part of the operator in terms of estimating the weight of a load can result in the crane tipping over.

Metric Impact:

A chart in the cab of the crane indicates, for varying load sizes, the angle at which the boom is to be set. With the advent of loads labeled in kilograms or metric tons, the operator will either have to interpret this data or be provided with a supplemental chart showing boom angles as a function of metric load sizes.

JOB HAZARD WORKSHEET

Occupation: Construction Crane Operator

Job Task:

Determine the load capacity of a stiff leg construction crane at various lengths along its boom. The boom on a stiff leg construction crane remains horizontal at the top of the crane and rotates. The load is lifted by a hook traveling the length of the boom and operating against counter weight. The amount of load that the boom can lift is a direct function of the distance between the load and the base of the crane.

Hazard:

An error in judgment regarding the size of a given load may result in the boom being unable to lift a load of a given length. As a result, the boom may collapse.

Metric Impact:

A chart in the cab of the crane indicates, for varying load sizes, the distance at which the boom can be used. With the advent of loads labeled in kilograms or metric tons, the operator will either have to interpret this data or be provided with a supplemental chart showing boom lengths as a function of metric load sizes.

JOB HAZARD WORKSHEET

Occupation: Construction Crane Operator

Job Task:

Select appropriate slings for lifting a particular load. In lifting a load with a crane, slings consisting of rope, cable, canvas, or other material are placed under the load at various points and connect with the hook at the end of the crane's cable. All slings have ratings to identify the number of pounds or tons they can safely lift. Some are marked and some are not marked, and the worker selects the sling on the basis of his experience.

Hazard:

Selection of an inappropriate sling -- that is, one that is not capable of supporting a particular load -- can result in failure of the sling when the load is being lifted, leading to shifting of the load and possible dropping of the load once it has been lifted off the ground.

Metric Impact:

With the advent of labeling of loads in kilograms or metric tons, it may be difficult for individual operators to readily identify the appropriate slings to support various loads.

JOB HAZARD WORKSHEET

Occupation: Garage and Gas Station Operators

Job Task:

Inflate tire pressure to manufacturer's recommended pressure.

Hazard:

Over- or under-inflation of the tire may result in improper wear and improper usage once the tire has been put back on the vehicle. Severe over-pressure may result in an explosion that would dislodge the tire from its rim, thereby causing the operator personal injury. Improper inflation may increase wear and contribute to tire failure, thus causing injury to the operator.

Metric Impact:

Tire pressures are now labeled in pounds per square inch and some are also labeled in megapascals. The relative size of megapascals and pounds per square inch is substantially different. An operator with an appropriate tire gauge should be able to distinguish megapascals from pounds per square inch. However, if an inappropriately labeled pressure gauge is produced, it may be possible to confuse the relative sizes of pascals and pounds per square inch in certain situations.

JOB HAZARD WORKSHEET

Occupation: Garage and Gas Station Operators

Job Task:

Use of correctly sized wrenches, such as box end, open end, or socket wrenches, to loosen bolts.

Hazard:

A typical hazard associated with this task is the wrench slipping on the bolt, thereby causing the worker to injure his hands or fingers in varying degrees of severity (from cuts and bruises to fractures).

Metric Impact:

As a result of the new even millimeter size wrenches, garage operators will be required to use either metric or inch wrenches, depending upon the particular bolt. Since it is difficult to clearly identify these bolts in most situations, an operator could grab the wrong size wrench, thereby possibly increasing the chances of it slipping and injuring his hand.

JOB HAZARD WORKSHEET

Occupation: Garage and Gas Station Operators

Job Task:

Tightening bolts to a specified torque, using a torque wrench.

Hazard:

Over-torqueing a bolt can result in the bolt stripping off at the threads and damaging the thread part, fracturing at the head, and leaving the remainder of the bolt in the part, or possible failure at a later date.

Metric Impact:

Torque specifications are carefully designed by manufacturers to provide for appropriate operation of various mechanical devices. These are presently specified *in foot-pounds or ounce-inches* of torque. All metric units will be in Newton meters (Nm). These units will occur in a substantially different range than do the current customary units.

JOB HAZARD WORKSHEET

Occupation: Welders and Cutters

Job Task:

Setting gas pressures on oxyacetylene welding equipment.

Hazard:

Inappropriate setting of the oxygen in acetylene pressures in an oxyacetylene welding system can cause the mixture to burn irregularly. The delivery of acetylene at a pressure over 15 PSI can cause the gas to disassociate explosively without proper addition of oxygen.

Metric Impact:

The change from pounds per square inch to kilopascals will be a significant change in the units used in pressure gauges.

JOB HAZARD WORKSHEET

Occupation: Welders and Cutters

Job Task:

Establishing the feed seed and speed rates for automatic welding machines.

Hazard:

Inappropriate setting of the wire feed rate or welding speed rate for the anode can cause automated electric welding equipment to behave erratically. This can cause excess hot metal to dislodge from the welding process and expose workers to burns.

Metric Impact:

These feed rates will change from feet per second to centimeters or millimeters per second.

JOB HAZARD WORKSHEET

Occupation: Chemical Processing

Job Task:

Batch formulation or mixing of appropriate amounts of chemicals to produce a particular chemical product. This includes selection of the raw materials, selection of the pumps to be used in transporting the materials from bulk storage to the process plant, and calculation of specific amounts of materials to be used.

Hazard:

In many cases, the mixing of inappropriate amounts of chemicals in a batch may only result in producing a batch of chemical product that is unusable. However, in some cases, such mismatching can cause a chemical reaction to proceed uncontrollably and create excess heat, pressure, or other reactions that can endanger workers.

Metric Impact:

Metric use will include changes in the units used to measure bulk materials from pounds to kilograms, or from gallons to liters or cubic meters, and changes in pump capacity from gallons per minute to liters per minute or hundreds of liters per minute.

JOB HAZARD WORKSHEET

Occupation: Chemical Processing

Job Task:

Physical handling of individually bagged chemical products.

Hazard:

Back strain caused by over-exertion while lifting amounts greater than physically tolerable.

Metric Impact:

The change to a new size for bag standards in chemical processes -- that of 25 kilograms or approximately 55 pounds -- may increase the exposure of workers to back strain.

JOB HAZARD WORKSHEET

Occupation: Structural Metal Workers

Job Task:

Assembly of structural steel. The major steel components are often bolted together instead of being riveted or welded. When such fasteners are used, they must be tightened to a specified torque according to the design specifications. This is accomplished by using a torque wrench when tightening the bolts.

Hazard:

Improperly tightening fasteners may result in eventual failure of the fastener if over tightened, or eventual loosening of the fastener if not tightened sufficiently.

Metric Impact:

With the change from foot-pounds to Newton-meters in torque measurement, it may be possible for a worker to misinterpret the data when tightening fasteners on a construction site.

JOB HAZARD WORKSHEET

Occupation: Plumbers and Pipefitters

Job Task:

Upon completion of piping installation, many facilities require pressurized testing of the piping to ensure that it meets design specifications. This is done by applying the appropriate fluid or gas under pressure and temperature test conditions and monitoring the piping configuration.

Hazard:

Under testing conditions, the pressure and temperature within the piping configuration must be raised to a sufficient level to verify the integrity of the piping. If this level is not reached, the test cannot be deemed adequate; and if an excessive amount of pressure or temperature is applied, this may result in failure of the piping system.

Metric Impact:

With the change from pounds per square inch to Pascals or megaPascals combined with the change in temperature from Farhenheit to degrees Celsius, it may possible for test specifications to be misinterpreted in the conduct of plumbing and piping testing.

ATTACHMENT III.10.14

JOB HAZARD WORKSHEET

Occupation: Auto and Truck Mechanics

Job Task:

Testing pressurized systems for engine cooling, braking, and air conditioning. Each of these systems requires periodic testing of the pressurized fluids to verify normal operation of the system. This is accomplished by use of a test instrument and a pressure gauge to make test measurements.

Hazard:

Testing at an extremely high pressure may result in rupture of the system; testing at lower than designed pressure may not provide a valid test of the equipment.

Metric Impact:

With the change from pounds per square inch to Pascals or megaPascals, it may possible for a mechanic to misinterpret the test data when conducting a pressurized test.

JOB HAZARD WORKSHEET

Occupation: Forklift and Tow Motor Operators

Job Task:

Ensuring that an object to be lifted does not exceed the capacity of the forklift.

Hazard:

If the item to be lifted exceeds the capacity of the forklift vehicle, it may result in the vehicle being tipped over during operation, and the object being dropped on co-workers or the operator being injured.

Metric Impact:

If items being warehoused are labeled in metric units of weight (kilograms or metric tons) and not labeled in equivalent customary units, it may be difficult for an operator to properly estimate the ability of the vehicle to lift a specific object.

JOB HAZARD WORKSHEET

Occupation: Electricians

Job Task:

Selection of appropriate conductor sizes when wiring a facility. Selection of wire sizes is a function of the current to be carried and is based upon wire gauge size (which implies the area of the wire specified in circular mils). Selection of a conductor that is too small may result in an electrical hazard. Selection of wire sizes too large incurs additional cost for the project.

Hazard:

Selection of an undersized electrical conductor may result in an electrical overload of the building, which could cause an electrical fire.

Metric Impact:

With the change from the established U.S. wire gauge sizes to some new and unfamiliar metric-based standards, it may be possible for electricians to misinterpret job specifications when wiring a building. This misinterpretation might result in a selection of undersized wires for installation.

ATTACHMENT III.10.17

JOB HAZARD WORKSHEET

Occupation: Airline Pilots

Job Task:

Deciding to continue a take-off or abort a take-off depends upon runway conditions and the operational characteristics of the aircraft. In a normal take-off, the airline pilot must decide, based upon aircraft performance, if he has sufficient runway to abort safely. In unseasonable weather conditions, the local controller will usually keep the pilot advised by "reading off" the length of remaining runway, expressed in thousands of feet.

Hazard:

Miscommunication of information from the controller to the pilot, or the provision of unclear information, could lead to confusion and misjudgment on the part of the airline pilot.

Metric Impact:

Pilot confusion about remaining runway may occur when the pilot is unsure as to whether the controller is expressing the runway length in metric or customary units.

JOB HAZARD WORKSHEET

Occupation: Millwrights

Job Task:

Installation and maintenance of heavy equipment. In the course of installing manufacturing equipment, selection of appropriate fasteners is a normal part of the installation.

Hazard:

Inappropriate selection of fasteners may result in fasteners that strip the threads that hold them in place, or otherwise violate the integrity of the hardware installation. This failure may cause a safety hazard.

Metric Impact:

With the continued mixed use of metric and inch fasteners on many manufactured items, it may be possible during maintenance or installation to insert an inch-sized fastener into metric threads, or vice versa, since some of these thread sizes appear to be compatible. This may lead to fastener failure at some future date.

IV. FINDINGS AND CONCLUSIONS

This section of the report summarizes the research team's findings and conclusions based on the data analysis conducted for this study.

The research team's analysis of metric change and safety hazards indicates that there are, in fact, situations in which change to metric measurement may create increased exposure to hazards for the worker, co-workers, or the general public. It is, however, extremely difficult to quantify this potential increase in occupational hazards with any clarity because of the many subtle issues associated with occupational injuries. The major conclusions from the study are summarized below.

A. NO METRIC HAZARD EXPERIENCE WAS IDENTIFIED

There does not appear to be any industry hazard experience directly related to metric conversion. No data exist on metric safety hazards, and no one in industry is collecting such data. In many instances, hypothetical scenarios were provided that characterize the potential for hazard, but none of these scenarios could be substantiated. The literature, occupational injury data, and hazard data do not provide any information relating metric change to occupational injuries.

B. SPECIFIC JOB TASKS ARE ASSOCIATED WITH POTENTIAL METRIC HAZARDS

In the analysis of job hazards, it was determined that certain required tasks in many occupational areas can be associated with increased hazard exposure as a result of the change to metric measurement. It is only when these particular tasks are part of a job, and that job is going through the transition from customary measurement to metric measurement, that an increase in hazard exposure might occur. Specific occurrences related to the tasks include:

- Worker exercises judgment in using measurement. While many occupations involve the use of measurement units, it is only when an individual worker must specifically interpret or apply judgment to those measurements that a metric hazard might occur. This judgment can take two forms -- reading an exact measurement from a dial, such as temperature or pressure, or having to convert from an inch dial to a metric number or from a metric dial to an inch number.

- Communication of a measurement value between two workers. In many occupations, two or more workers are involved in a communication of measurement units from one location to another. This may be done by voice or by radio, and often is done by using the numerical

value without attaching the measurement units. For example, a worker might communicate 200 when he actually means 200°F. During the transition period from customary units to metric units, this communication may provide substantial opportunities for workers to misinterpret the units being communicated.

Conditioned response in emergency situations. While many occupational jobs and tasks are performed routinely, there are a number of tasks that require a conditioned response to an emergency situation. In these situations, the worker is faced with a severe time constraint and must make judgments quickly, with little or no time to consider the issue of inch-metric conversion or which measurement data he is being presented with. Often the worker relies on a conditioned response based on years of experiential data, even though the use of metric measurement may make that experiential data totally inappropriate in a specific situation.

C. WELL-PLANNED METRIC CHANGE PROGRAMS REDUCE HAZARD POTENTIAL

Metric change programs, whether they are sector plans, corporate plans, or Federal agencies' plans, can minimize the potential for metric hazards. To the extent that such plans allow extended periods of usage for both customary units and metric units, with the inherent conversion between the two measurement systems that this type of approach often requires, there may be an increase in the potential for hazards. The potential for worker exposure to hazards may also increase if there is no provision for job hazard analysis and if safety professionals are not included in the planning phase of metric conversion programs. A well-planned metric change program with appropriate training programs and with a minimum use of both inch and metric units should not provide for increased occupational hazard exposure for the workers.

D. INDUSTRIAL SAFETY PROGRAMS CAN REDUCE METRIC HAZARDS

Professional safety experts working in industry are experienced at managing the introduction of new technology into the workplace. These individuals have dealt with increased safety hazards resulting from such technology as laser measurement in the workforce. Their involvement in metric planning, metric training programs, and procedural analysis can reduce the potential exposure to hazards resulting from metric change.

E. METRIC ISSUES ARE UNRESOLVED IN THE AVIATION INDUSTRY

At the present time, the aviation industry is experiencing increased usage of metric measurement worldwide. At the international level, metric measurement has become the accepted language for aviators with the approval (November 26, 1981) of Amendment 13 to Annex 5, "Units of Measure to be

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EFFECTS OF METRIC CHANGE ON SAFETY IN THE WORKPLACE FOR SELECTE--ETC(U)
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Used in Air and Ground Operations", the International Civil Aviation Organization (ICAO) regulations. While individual countries will implement metric units into aviation operations at their own pace, in many countries the use of metric instrumentation is becoming commonplace. In contrast, within the United States, certified U.S. carrier aircraft are equipped with customary instrumentation. This situation presents the potential for airborne conversion as U.S. aviators fly in a metric measurement environment outside of the United States and as metric oriented aviators fly in the U.S.'s customary measurement aviation environment. Many safety issues related to aviation's adoption of metric measurement can be identified in the U.S. periodicals, but these have not yet been resolved; nor has a comprehensive aviation conversion plan been developed and endorsed by U.S. industry.

V. RECOMMENDATIONS

The following are Middlesex Research Center's recommendations to the U.S. Metric Board. These recommendations, if implemented, will reduce the potential for increased safety hazards resulting from metric conversion.

A. THE U.S. METRIC BOARD SHOULD CONSIDER SAFETY ISSUES WHEN REVIEWING SECTOR PLANS

Under the provisions of Public Law 94-168, the U.S. Metric Board has the responsibility of reviewing industry conversion plans. A procedure for reviewing these plans has been promulgated by the Metric Board and provides for a coordinative role on the part of USMB. In conducting reviews of sector plans, the U.S. Metric Board should ensure that industry safety professionals have been involved in the development of each plan. The extent of involvement of these safety professionals will vary from industry to industry, but it is important that the U.S. Metric Board provide a vehicle for ascertaining that safety professionals have in fact analyzed the impact of a proposed metric conversion program on occupational safety.

B. ANMC SHOULD INVOLVE SAFETY PROFESSIONALS IN SECTOR PLANNING

The U.S. Metric Board should encourage the American National Metric Council (ANMC), its industry members, and other professional associations to include safety professionals in all metric planning activities. This would be accomplished either by having ANMC provide the safety expertise as a staff function or by ensuring through its sector planning process that the industry members involved in the planning provide for ongoing safety professional input in the planning process. This input should specifically focus on reviewing metric conversion plans from the perspective of job hazard analysis and occupational safety programs. In addition, safety professionals should be involved in the development of metric training programs within industry.

C. THE ICMP AND THE MOC SHOULD INVOLVE SAFETY PROFESSIONALS IN ALL FEDERAL METRIC CHANGE PLANNING

The U.S. Metric Board should encourage the Interagency Committee on Metric Policy (ICMP) and the Metric Operating Committee (MOC) to include Federal safety professionals in metric planning activities, since each Federal agency has designated a focal point for metric planning. In most cases, the Federal agencies also have a focal point for occupational safety; therefore, the MOC should develop a procedure for linking individual agency safety professionals into each agency's metric planning

activities. Again, these activities should focus on involving safety professionals in the development of metric training programs, metric conversion activities, and an overall review of the impact of the conversion plans on occupational safety.

D. A STUDY OF METRIC HAZARDS IN AVIATION SHOULD BE CONDUCTED

The aviation industry within the United States has many metric issues that are currently unresolved. These metric issues, if unresolved, may cause increased exposure to hazards as a result of U.S. usage of both metric and customary units in aviation. Therefore, a study of these issues is appropriate. This study should be conducted by an independent professional organization that is knowledgeable in both international measurement and metric conversion activities, and is technically competent to understand the technical complexities associated with the airline pilot occupation. If this study is to provide any value to the U.S. aviation industry, it should be initiated immediately, since metric usage is increasing internationally at a rapid pace and U.S. industry is forced to deal with these metric issues on a day-to-day basis. Under the provisions of PL 94-168, this particular study would logically come under the research activity of the U.S. Metric Board. However, with the future of the Board as yet undetermined by Congressional appropriation, it is not clear who should be responsible for assuming a leadership role in this study. The organizations that logically could be involved would include the U.S. Metric Board, the Federal Aviation Administration, the Airline Pilots Association (APA), the American National Metric Council, and possibly other organizations.

APPENDIX I

METRIC SAFETY HAZARDS STUDY

FORUM/LOS ANGELES

February 2, 1982

AGENDA

MORNING SESSION

Welcome and Study Background

Review of Occupational Areas and Occupation/Hazard Data

Discussion of Job/Task Analysis and Job Safety Analysis Data for Selected Occupations

BREAK

Review of Metric Measurement

Presentation of Sample Metric Job Hazard Analysis

LUNCH

AFTERNOON SESSION

Identification of Specific Potential Metric Safety Hazards and Analysis

Consideration of Preventive Mechanisms for Metric Safety Hazards and Associated Costs of Those Mechanisms

Identification of Associated Public Hazards

METRIC SAFETY HAZARDS STUDY

FORUM/LOS ANGELES

February 2, 1982

TABLE OF CONTENTS

BACKGROUND: WORKER TOOL AND TRAINING SAFETY ISSUES STUDY

The Metric Conversion Act of 1975 (P.L. 94-168) established the U.S. Metric Board as an independent Federal Agency responsible for coordinating the voluntary conversion of the United States to the metric system. In passing the Act, the Congress declared that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish the United States Metric Board to coordinate the voluntary conversion to the metric system.

The U.S. Metric Board consists of 17 members who are representative of the various sectors of the United States' economy, including representatives for engineers, scientists, the National Association of Manufacturers, the U.S. Chamber of Commerce, the AFL-CIO, the Governor's Conference, small business, construction, the National Conference on Weights and Measures, educators, and consumers. Among the various responsibilities and functions mandated in the Law, the Board is "... to consult with and to take into account the interests, views, and conversion costs of U.S. commerce and industry ..." The Act instructs the Board in Section 6(8) "to collect, analyze, and publish information about the extent of usage of metric measurements, evaluate the costs and benefits of metric usage; make efforts to minimize any adverse effects resulting from increasing metric usage." Section 6(9) directs the Board "to conduct research, publish results and recommend to Congress and to the President such actions as may be appropriate to deal with any unresolved problems, issues and questions pertaining to metric usage and conversion."

It is the policy of the U.S. Metric Board that metrication is to proceed by the voluntary, coordinated decisions of each segment and sector of our society. The role of the Board is to ensure that changeovers take place in the most economic and effective way and to encourage all interested parties to participate in the planning process.

As a result of Public Law 94-168, the U.S. Metric Board was authorized to undertake certain types of research regarding the effects of metric conversion. Under the leadership of its research committee, the U.S. Metric Board has determined that the impact of metric conversion on individual workers is an important area of research.

During October of 1979, the U.S. Metric Board began its initial research in the area of Worker Tools and Training. This (1979-1980) study, entitled "The Effects of Metric Conversion on Measurement and Dimensional Sensitive Occupations", was conducted in two phases. Phase IA analyzed the Dictionary of Occupational Titles (DOT) to determine which occupational areas seemed to be measurement sensitive. These occupational areas were used to formulate research objectives for future studies. The results of

Phase IA were used to identify the initial goals for the current (1980-1981) Phase II study of tool and training issues. Phase IB of the study is not yet completed.

In April of 1981, Middlesex Research Center completed Phase II of the Worker Tool and Training study and, in June, presented its findings to the U.S. Metric Board at public hearings in Charlotte, North Carolina. A copy of that report is included in this mailing. Part of that presentation included a recommendation that potential worker safety hazards be explored. In September, the Metric Board requested that the study be continued by MRC on an urgent basis, since the Worker Tool and Training Study was not intended to focus on a detailed, in-depth analysis of safety issues. Based on information that was gathered during on-site visits, MRC had concluded that there is a potential for increased safety hazards in certain job tasks. For example, a worker whose job involves lifting heavy equipment with an overhead crane may experience difficulty in safely estimating the weight of units if he is accustomed to dealing with customary weights and the marking on the units have been changed from U.S. tons to metric tons. There are a number of specific job tasks that appear to be susceptible to increased safety problems as a result of metric conversion; therefore, MRC recommended that the U.S. Metric Board examine the issue of occupational safety in more detail than was possible in the Worker Tool and Training Study.

The following paragraphs present the objectives, scope, and tasks mutually agreed upon by the U.S. Metric Board and Middlesex Research Center for the current study.

I. STUDY OBJECTIVE

In changing dimensions in work with which people have been long familiar, it is possible that instinctive actions and reactions, which are the result of long training, may cause danger to workers.

The Objective of this study is to determine the extent to which worker health and safety issues may arise in conversion to the metric system, and the nature of such issues, if and when they arise.

This is to be done through the selection of particular occupations for examination on the basis of their particular characteristics which might lead to health and safety problems. Examples might be such occupations as airline pilots, automobile mechanics, nuclear technicians, etc. Of course, the study should focus not only on highly measurement sensitive occupations, but also on known hazardous occupations that are to some degree measurement sensitive.

II. SCOPE

The scope of this study is exploratory: to identify whether, and if so which, health and safety problems might arise during metric transitions.

Whether or not a transition is actually contemplated or in progress is not relevant to the study. This study is to serve to alert the U.S. Metric Board to potential problems in the area studied, as well as actual ones.

The issues for this study fall into three areas: (1) the accidents and illnesses that befall workers, and how they arise; (2) costs related issues such as insurance, safety training, and lost time; and (3) the existence of, impact of, and need for legislation and regulations. The study emphasis is to be placed on the first of these three areas.

III. TASKS

Identify safety hazards in metric conversion. A program of interviews with persons directly involved with the affected occupations will be carried out. Such persons as nurses and health officers at firms and military installations, safety engineers, industrial insurance agents, metric coordinators, shop foremen, and workers should be interviewed. These interviews are to be conducted in such a way as to portray the extent of any effects or problems rather than to find interesting, though isolated, instances. These interviews are to be conducted in three phases, as follows.

1. Research will be conducted to identify the specific opportunities for safety hazards as a result of metric units replacing customary units. This research will identify specific incidences involving tasks performed within certain occupations and the individual measurement units involved.

2. Determine results if these hazards are not properly addressed. Following identification of the opportunities for safety hazards, the research team will determine the nature of the potential results of safety issues not being properly addressed. In conducting this analysis, the research team will identify the specific hazards that might be presented to an individual or a group of individuals employed in certain occupations while performing specified tasks. Where possible, the exact nature of the consequences -- that is, exposure to a major hazard, possible loss of life, or possible failure of a part -- should be identified.

3. Outline preventive measures. Following identification of the specific occupational hazards that might be presented as a result of metric change, the research team will outline preventive measures that could be taken by industry to keep such hazards from occurring. These measures will include such things as educational programs, safety devices, awareness programs, and other positive actions that an individual industry or employer can take to reduce or eliminate the potential of safety hazards resulting from the change to metric units.

PROJECT PLAN

Middlesex Research Center recently submitted a report to the U.S. Metric Board on the findings of a study entitled, "Effects of Metric Change on Workers' Tools and Training". The USMB has engaged MRC to conduct an additional task for this study relating to potential safety hazards to workers that result from metric conversion.

The following is an overview of MRC's approach to the current task. The plan reflects the Statement of Work provided by the U.S. Metric Board Research Staff, as well as the input from the study consultants and the Advisory Panel members.

A. PURPOSE OF PROJECT

The purpose of the project is found in the recommendations of the research group that was involved in the Worker Tool and Training Study Phase II. In that study, there was a small effort to look at how worker safety might be impacted by metric conversion; however, the safety issue was grouped with other companion issues and received only cursory attention. Although resources for examining the safety issue were small, and it was not investigated in any depth, there appeared to be concerns in this area on the part of both the labor and the management groups that were interviewed. In some cases, certain measurements were not converted from customary to metric units because the firm preferred to avoid any potential safety hazards. This was most common in pressure measurements.

It became apparent to the research group that as more industries exercise the option of voluntary metric conversion, the potential for safety hazards could possibly increase. It was also clear that, in some companies (particularly those with highly measurement sensitive jobs), there was more planning, training, and information for and about metric use. In those companies, the potential safety hazards would probably be recognized. It is with the jobs that are particularly hazardous and not necessarily highly measurement sensitive that the possibility of accidents and resultant injuries might occur. Concurrent with this issue is the possibility that workers' mismeasurement may create a dangerous situation to the general public as well as to themselves.

B. PROJECT TASKS

1. Develop a draft project plan

   Following the initial planning meeting, the research staff will develop a project plan. This plan will outline the tasks and their

sequence. In addition, the plan will describe the research methodology that will be employed. The draft plan will be reviewed by the Advisory Panel during the week of October 19th, after which it will be presented to the U.S. Metric Board Research Staff on November 2nd for their review and approval.

2. Develop an Advisory Panel

The Advisory Panel will meet and agree upon a Project Plan. The Panel will be made up of people who have been recommended by the MRC staff, the U.S. Metric Board Research Staff, and those members of the Metric Board who have special concerns regarding labor and safety. The Panel will be versed in the project process and will meet on October 26th. At the October meeting, the Panel will be asked to review the project plan and make recommendations for augmenting and deleting as needed. Exhibit A provides a list of the Advisory Panel members.

An additional Advisory Panel meeting will be called if deemed necessary.

3. Identify the most hazardous occupations

The most hazardous occupations will be identified using statistical data from the Bureau of Labor Statistics and the National Safety Council, computer searches of the literature, and the expert opinions of industrial safety specialists.

4. Identify the measurement sensitive occupations

This task was done in the Worker Tool and Training Study. The occupations that were identified as being measurement sensitive in that study will be used for the current study. Exhibit B is a list of those occupations.

5. Hazardous/Measurement Sensitive Occupations Matrix

A matrix will be developed using the data from 3 and 4 above. This maxtrix will also show the worker population in order to identify the greatest number of workers facing both hazards and measurement sensitive tasks. This matrix is shown in Exhibit C.

A mechanism will be developed that not only illustrates the breakdown of the work force, but also highlights those occupations that are hazardous and those that are measurement sensitive.

6. The Prioritization of Occupations to Study

The research team will prioritize the occupations to be studied by use of weighting factors. The research staff will establish a weighting factor for the following:

- Hazard characteristics
- Measurement sensitivity characteristics
- Size of worker population
- Level of decisionmaking within job tasks
- Job/task relationship to potential public hazards.

An example of the weighting factor structure is shown in Exhibit D.

7. Address Federal Regulations Affected by Metric Change

Review selected Federal regulations that relate to the prioritized occupations and identify those regulatory areas that may require changes for safe use of SI measurement language. Exhibit E is an example of the measurements found in the OSHA regulations for one occupation.

8. Collect industry data

To maximize industry input to the study, MRC will conduct six to ten one-day forums on metric safety issues. The forums will be geographically distributed throughout the U.S., and participants will be solicited from industry, labor, and academia (see Exhibit F). Professional organizations and companies will be selected to participate in structured forums and to be used as data sources.

9. Problem identification

One or two scenarios will be developed illustrating the interrelatedness of worker mismeasurement and the creation of public hazard. A discussion of the mechanisms that could be employed to avert dangerous situations will be incorporated into the scenarios.

10. Analysis and final report

MRC will submit a final report to the U.S. Metric Board. The report will include a description of the occupations studied, reports on those studied, the case studies that reflect Federal regulations and public safety issues, and recommendations for prevention of the hazards and (if any) the related costs. (See Exhibit G for sample of analytical approach.)

C. PROJECT SCHEDULE

September 2, 1981	Planning meeting
September 9, 1981	Notes on planning meeting submitted
September 14, 1981	Advisory committee formed
October 19, 1981	Draft project plan submitted to Advisory Panel
October 26, 1981	Advisory Panel meets
November 2, 1981	Draft Project Plan submitted to USMB
November 5, 1981	Draft Project Plan approved or revised by USMB
November 1 - January 31, 1982	Data collection through forums described in Project Plan
February 1, 1982	Status Report
February 28, 1982	Submit Preliminary Draft Final Report
March 26, 1982	Submit Draft Final Report
April 3, 1982	Review with U.S. Metric Board
May 1, 1982	Submit Final Report and Executive Summary

EXHIBIT A

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EXHIBIT C

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY

The occupations shown below are based on injury and illnesses indexes and are for the private sector. Occupations listed have injury and illnesses indexes above the average for all occupations for an industry division. Data sources include: Exhibit B-1 of Effects of Metric Change on Workers Tools and Training, July 15, 1981, prepared by Middlesex Research Center, Inc.; U.S. Department of Labor, Bureau of Labor Statistics, Supplementary Data System, July 1981; Accident Facts, 1980 Edition, National Safety Council, and Page 27 of Accident Facts, 1979 Edition; Occupational Injuries & Illnesses in 1979 - Summary, U.S. Department of Labor, Bureau of Labor Statistics, July 1981; Occupational Injuries and Illnesses in the United States by Industry 1978, U.S. Department of Labor, Bureau of Labor Statistics, August 1980; and Dictionary of Occupational Titles (DOT).

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Millwrights				
Glaziers				
Sheetmetal workers				
Structural metal craft				
Plumbers & Pipefitters				
Carpenters & Appr.				
Asbestos & Insul. workers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 2)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Truck drivers				
Laborers (except farm)				
Mine operators, nec.				
Welders & Cutters				
Vehicle & Equip. cleaners				
Mechanics & Repairmen (Auto, etc.)				
Molders, metal				
Assemblers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 3)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Grindling Machine operators				
Forklift, tenmoter operators				
Freight, materials handlers				
Warehouse laborers				
Cleaning service workers				
Stock clerk & Store keepers				
Packers, Wrappers				
Delivery & Route Drivers				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 4)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Garbage collectors				
Machinists & appr.				
Garage workers, gas station attendants				
Meat cutters, Butchers				
Stock handlers				
Painters, Constr., Maintenance				
Transp. Equip. operators				
Electricians & appr.				

HAZARDOUS OCCUPATIONS AND METRIC SENSITIVITY
(continued - page 5)

Occupations	Worker Population	% of Total	Measurement Sensitivity	Comments
Laundry, dry cleaning				
Nursing aids, orderlies, attendants				
Vehicle & equipment handlers				
Food service workers				

EXHIBIT D

INITIAL STRUCTURE FOR PRIORITIZING OCCUPATIONS

		OCCUPATIONAL AREAS						
FACTORS	WEIGHT	GLAZIER	PLUMBER	CARPEN-TER		--	PACKERS	ELEC.
1. Hazard Statistical Data								
2. Worker Population								
3. SI Unit Complexity								
4. Extent of Dual Usage Required								
5. Degree of Job/Task Judgement								
6. Availability of Job/Task & Hazard Analys. Data								
7. *								
8. *								

*Other factors to be added later in this study.

EXHIBIT E

Subpart Q—Welding, Cutting, and Brazing

§ 1910.251 Definitions.

As used in this subpart:

(a) "Welder" and "welding operator" mean any operator of electric or gas welding and cutting equipment.

(b) "Approved" means listed or approved by a nationally recognized testing laboratory, such as Factory Mutual Engineering Corp., or Underwriters' Laboratories, Inc.

(c) All other welding terms are used in accordance with American Welding Society—Terms and Definitions—A3.0-1969.

§ 1910.252 Welding, cutting, and brazing.

(a) *Installation and operation of oxygen-fuel gas systems for welding and cutting*—(1) *General requirements.* (i) *Flammable mixture.* Mixtures of fuel gases and air or oxygen may be explosive and shall be guarded against. No device or attachment facilitating or permitting mixtures of air or oxygen with flammable gases prior to consumption, except at the burner or in a standard torch, shall be allowed unless approved for the purpose.

(ii) *Maximum pressure.* Under no condition shall acetylene be generated, piped (except in approved cylinder manifolds) or utilized at a pressure in excess of 15 p.s.i. gage pressure of 30 p.s.i. absolute pressure. (The 30 p.s.i. absolute pressure limit is intended to prevent unsafe use of acetylene in pressurized chambers such as caissons, underground excavations or tunnel construction.) This requirement is not intended to apply to storage of acetylene dissolved in a suitable solvent in cylinders manufactured and maintained according to U.S. Department of Transportation requirements, or to acetylene for chemical use. The use of liquid acetylene shall be prohibited.

(iii) *Apparatus.* Only approved apparatus such as torches, regulators or pressure-reducing valves, acetylene generators, and manifolds shall be used.

(iv) *Personnel.* Workmen in charge of the oxygen or fuel-gas supply equipment, including generators, and oxygen or fuel-gas distribution piping systems shall be instructed and judged competent by their employers for this important work before being left in charge. Rules and instructions covering the operation and maintenance of oxygen or fuel-gas supply equipment including generators, and oxygen or fuel-gas distribution piping systems shall be readily available.

(2) *Cylinders and containers*—(i) *Approval and marking.* (*a*) All portable cylinders used for the storage and shipment of compressed gases shall be constructed and maintained in accordance with the regulations of the U.S. Department of Transportation, 49 CFR Parts 171-179.

(*b*) Compressed gas cylinders shall be legibly marked, for the purpose of identifying the gas content, with either the chemical or the trade name of the gas. Such marking shall be by means of stenciling, stamping, or labeling, and shall not be readily removable. Whenever practical, the marking shall be located on the shoulder of the cylinder. This method conforms to the American National Standard Method for Marking Portable Compressed Gas Containers to Identify the Material Contained, ANSI Z48.1-1954.

(*c*) Compressed gas cylinders shall be equipped with connections complying with the American National Standard Compressed Gas Cylinder Valve Outlet and Inlet Connections, ANSI B57.1-1965.

(*d*) All cylinders with a water weight capacity of over 30 pounds shall be equipped with means of connecting a valve protection cap or with a collar or recess to protect the valve.

(ii) *Storage of cylinders—general.* (*a*) Cylinders shall be kept away from radiators and other sources of heat.

(*b*) Inside of buildings, cylinders shall be stored in a well-protected, well-ventilated, dry location, at least 20 feet from highly combustible materials such as oil or excelsior. Cylinders should be stored in definitely assigned places away from elevators, stairs, or gangways. Assigned storage spaces shall be located where cylinders will not be knocked over or damaged by passing or falling objects, or subject to

tampering by unauthorized persons. Cylinders shall not be kept in unventilated enclosures such as lockers and cupboards.

(c) Empty cylinders shall have their valves closed.

(d) Valve protection caps, where cylinder is designed to accept a cap, shall always be in place, hand-tight, except when cylinders are in use or connected for use.

(iii) *Fuel-gas cylinder storage.* Inside a building, cylinders, except those in actual use or attached ready for use, shall be limited to a total gas capacity of 2,000 cubic feet or 300 pounds of liquefied petroleum gas.

(a) For storage in excess of 2,000 cubic feet total gas capacity of cylinders or 300 pounds of liquefied petroleum gas, a separate room or compartment conforming to the requirements specified in paragraphs (*6*) (vi)(*a*) (*8*) and (*9*) of this paragraph shall be provided, or cylinders shall be kept outside or in a special building. Special buildings, rooms or compartments shall have no open flame for heating or lighting and shall be well ventilated. They may also be used for storage of calcium carbide in quantities not to exceed 600 pounds, when contained in metal containers complying with paragraphs (a)(7)(i) (*a*) and (*b*) of this paragraph. Signs should be conspicuously posted in such rooms reading, "Danger—No Smoking, Matches or Open Lights," or other equivalent wording.

(b) Acetylene cylinders shall be stored valve end up.

(iv) *Oxygen storage.* (*a*) Oxygen cylinders shall not be stored near highly combustible material, especially oil and grease; or near reserve stocks of carbide and acetylene or other fuel-gas cylinders, or near any other substance likely to cause or accelerate fire; or in an acetylene generator compartment.

(b) Oxygen cylinders stored in outside generator houses shall be separated from the generator or carbide storage rooms by a noncombustible partition having a fire-resistance rating of at least 1 hour. This partition shall be without openings and shall be gastight.

(c) Oxygen cylinders in storage shall be separated from fuel-gas cylinders or combustible materials (especially oil or grease), a minimum distance of 20 feet or by a noncombustible barrier at least 5 feet high having a fire-resistance rating of at least one-half hour.

(d) Where a liquid oxygen system is to be used to supply gaseous oxygen for welding or cutting and the system has a storage capacity of more than 13,000 cubic feet of oxygen (measured at 14.7 p.s.i.a. and 70° F.), connected in service or ready for service, or more than 25,000 cubic feet of oxygen (measured at 14.7 p.s.i.a. and 70° F.), including unconnected reserves on hand at the site, it shall comply with the provisions of the Standard for Bulk Oxygen Systems at Consumer Sites, NFPA No. 566-1965.

(v) *Operating procedures.* (*a*) Cylinders, cylinder valves, couplings, regulators, hose, and apparatus shall be kept free from oily or greasy substances. Oxygen cylinders or apparatus shall not be handled with oily hands or gloves. A jet of oxygen must never be permitted to strike an oily surface, greasy clothes, or enter a fuel oil or other storage tank.

(b) (*1*) When transporting cylinders by a crane or derrick, a cradle, boat, or suitable platform shall be used. Slings or electric magnets shall not be used for this purpose. Valve-protection caps, where cylinder is designed to accept a cap, shall always be in place.

(*2*) Cylinders shall not be dropped or struck or permitted to strike each other violently.

(*3*) Valve-protection caps shall not be used for lifting cylinders from one vertical position to another. Bars shall not be used under valves or valve-protection caps to pry cylinders loose when frozen to the ground or otherwise fixed; the use of warm (not boiling) water is recommended. Valve-protection caps are designed to protect cylinder valves from damage.

(*4*) Unless cylinders are secured on a special truck, regulators shall be removed and valve-protection caps, when provided for, shall be put in place before cylinders are moved.

(*5*) Cylinders not having fixed hand wheels shall have [illegible], handles, or

nonadjustable wrenches on valve stems while these cylinders are in service. In multiple cylinder installations only one key or handle is required for each manifold.

(*6*) Cylinder valves shall be closed before moving cylinders.

(*7*) Cylinder valves shall be closed when work is finished.

(*8*) Valves of empty cylinders shall be closed.

(*9*) Cylinders shall be kept far enough away from the actual welding or cutting operation so that sparks, hot slag, or flame will not reach them, or fire-resistant shields shall be provided.

(*10*) Cylinders shall not be placed where they might become part of an electric circuit. Contacts with third rails, trolley wires, etc., shall be avoided. Cylinders shall be kept away from radiators, piping systems, layout tables, etc., that may be used for grounding electric circuits such as for arc welding machines. Any practice such as the tapping of an electrode against a cylinder to strike an arc shall be prohibited.

(*11*) Cylinders shall never be used as rollers or supports, whether full or empty.

(*12*) The numbers and markings stamped into cylinders shall not be tampered with.

(*13*) No person, other than the gas supplier, shall attempt to mix gases in a cylinder. No one, except the owner of the cylinder or person authorized by him, shall refill a cylinder.

(*14*) No one shall tamper with safety devices in cylinders or valves.

(*15*) Cylinders shall not be dropped or otherwise roughly handled.

(*16*) Unless connected to a manifold, oxygen from a cylinder shall not be used without first attaching an oxygen regulator to the cylinder valve. Before connecting the regulator to the cylinder valve, the valve shall be opened slightly for an instant and then closed. Always stand to one side of the outlet when opening the cylinder valve.

(*17*) A hammer or wrench shall not be used to open cylinder valves. If valves cannot be opened by hand, the supplier shall be notified.

(*18*) (*i*) Cylinder valves shall not be tampered with nor should any attempt be made to repair them. If trouble is experienced, the supplier should be sent a report promptly indicating the character of the trouble and the cylinder's serial number. Supplier's instructions as to its disposition shall be followed.

(*ii*) Complete removal of the stem from a diaphragm-type cylinder valve shall be avoided.

(c) (*1*) Fuel-gas cylinders shall be placed with valve end up whenever they are in use. Liquefied gases shall be stored and shipped with the valve end up.

(*2*) Cylinders shall be handled carefully. Rough handling, knocks, or falls are liable to damage the cylinder, valve or safety devices and cause leakage.

(*3*) Before connecting a regulator to a cylinder valve, the valve shall be opened slightly and closed immediately. The valve shall be opened while standing to one side of the outlet; never in front of it. Never crack a fuel-gas cylinder valve near other welding work or near sparks, flame, or other possible sources of ignition.

(*4*) Before a regulator is removed from a cylinder valve, the cylinder valve shall be closed and the gas released from the regulator.

(*5*) Nothing shall be placed on top of an acetylene cylinder when in use which may damage the safety device or interfere with the quick closing of the valve.

(*6*) If cylinders are found to have leaky valves or fittings which cannot be stopped by closing of the valve, the cylinders shall be taken outdoors away from sources of ignition and slowly emptied.

(*7*) A warning should be placed near cylinders having leaking fuse plugs or other leaking safety devices not to approach them with a lighted cigarette or other source of ignition. Such cylinders should be plainly tagged; the supplier should be promptly notified and his instructions followed as to their return.

(*8*) Safety devices shall not be tampered with.

(9) Fuel-gas shall never be used from cylinders through torches or other devices equipped with shutoff valves without reducing the pressure through a suitable regulator attached to the cylinder valve or manifold.

(10) The cylinder valve shall always be opened slowly.

(11) An acetylene cylinder valve shall not be opened more than one and one-half turns of the spindle, and preferably no more than three-fourths of a turn.

(12) Where a special wrench is required it shall be left in position on the stem of the valve while the cylinder is in use so that the fuel-gas flow can be quickly turned off in case of emergency. In the case of manifolded or coupled cylinders at least one such wrench shall always be available for immediate use.

(3) *Manifolding of cylinders*—(i) *Fuel-gas manifolds.* (*a*) Manifolds shall be approved either separately for each component part or as an assembled unit.

(*b*) Except as provided in paragraph (a)(3)(i)(*c*) of this section fuel-gas cylinders connected to one manifold inside a building shall be limited to a total capacity not exceeding 300 pounds of liquefied petroleum gas or 3,000 cubic feet of other fuel-gas. More than one such manifold with connected cylinders may be located in the same room provided the manifolds are at least 50 feet apart or separated by a noncombustible barrier at least 5 feet high having a fire-resistance rating of at least one-half hour.

(*c*) Fuel-gas cylinders connected to one manifold having an aggregate capacity exceeding 300 pounds of liquefied petroleum gas or 3,000 cubic feet of other fuel-gas shall be located outdoors, or in a separate building or room constructed in accordance with paragraphs (a)(6)(vi)(*a*) (*8*) and (*9*) of this section.

(*d*) Separate manifold buildings or rooms may also be used for the storage of drums of calcium carbide and cylinders containing fuel gases as provided in paragraph (a)(2)(iii) of this section. Such buildings or rooms shall have no open flames for heating or lighting and shall be well-ventilated.

(*e*) High-pressure fuel-gas manifolds shall be provided with approved pressure regulating devices.

(ii) *High-pressure oxygen manifolds (for use with cylinders having a Department of Transportation service pressure above 200 p.s.i.g.).* (*a*) Manifolds shall be approved either separately for each component part or as an assembled unit.

(*b*) Oxygen manifolds shall not be located in an acetylene generator room. Oxygen manifolds shall be separated from fuel-gas cylinders or combustible materials (especially oil or grease), a minimum distance of 20 feet or by a noncombustible barrier at least 5 feet high having a fire-resistance rating of at least one-half hour.

(*c*) Except as provided in subdivision (*d*) of this subdivision oxygen cylinders connected to one manifold shall be limited to a total gas capacity of 6,000 cubic feet. More than one such manifold with connected cylinders may be located in the same room provided the manifolds are at least 50 feet apart or separated by a noncombustible barrier at least 5 feet high having a fire-resistance rating of at least one-half hour.

(*d*) An oxygen manifold, to which cylinders having an aggregate capacity of more than 6,000 cubic feet of oxygen are connected, should be located outdoors or in a separate noncombustible building. Such a manifold, if located inside a building having other occupancy, shall be located in a separate room of noncombustible construction having a fire-resistance rating of at least one-half hour or in an area with no combustible material within 20 feet of the manifold.

(*e*) An oxygen manifold or oxygen bulk supply system which has storage capacity of more than 13,000 cubic feet of oxygen (measured at 14.7 p.s.i.a. and 70° F.), connected in service or ready for service, or more than 25,000 cubic feet of oxygen (measured at 14.7 p.s.i.a. and 70° F.), including unconnected reserves on hand at the site, shall comply with the provisions of the Standard for Bulk Oxygen Systems at Consumer Sites, NFPA No. 566-1965.

(*f*) High-pressure oxygen manifolds shall be provided with approved pressure-regulating devices.

(iii) *Low-pressure oxygen manifolds (for use with cylinders having a Department of Transportation service pressure not exceeding 200 p.s.i.g.).* (*a*) Manifolds shall be of substantial construction suitable for use with oxygen at a pressure of 250 p.s.i.g. They shall have a minimum bursting pressure of 1,000 p.s.i.g. and shall be protected by a safety relief device which will relieve at a maximum pressure of 500 p.s.i.g. DOT-4L200 cylinders have safety devices which relieve at a maximum pressure of 250 p.s.i.g. (or 235 p.s.i.g. if vacuum insulation is used).

(*b*) Hose and hose connections subject to cylinder pressure shall comply with paragraph (a)(5)(v) of this section. Hose shall have a minimum bursting pressure of 1,000 p.s.i.g.

(*c*) The assembled manifold including leads shall be tested and proven gas-tight at a pressure of 300 p.s.i.g. The fluid used for testing oxygen manifolds shall be oil-free and not combustible.

(*d*) The location of manifolds shall comply with subdivisions (ii) (*b*), (*c*), (*d*), and (*e*) of this subdivision.

(*e*) The following sign shall be conspicuously posted at each manifold:

Low-Pressure Manifold

Do Not Connect High-Pressure Cylinders

Maximum Pressure—250 P.S.I.G.

(iv) *Portable outlet headers.* (*a*) Portable outlet headers shall not be used indoors except for temporary service where the conditions preclude a direct supply from outlets located on the service piping system.

(*b*) Each outlet on the service piping from which oxygen or fuel-gas is withdrawn to supply a portable outlet header shall be equipped with a readily accessible shutoff valve.

(*c*) Hose and hose connections used for connecting the portable outlet header to the service piping shall comply with paragraph (a)(5)(v) of this section.

(*d*) Master shutoff valves for both oxygen and fuel-gas shall be provided at the entry end of the portable outlet header.

(*e*) Portable outlet headers for fuel-gas service shall be provided with an approved hydraulic back-pressure valve installed at the inlet and preceding the service outlets, unless an approved pressure-reducing regulator, an approved back-flow check valve, or an approved hydraulic back-pressure valve is installed at each outlet. Outlets provided on headers for oxygen service may be fitted for use with pressure-reducing regulators or for direct hose connection.

(*f*) Each service outlet on portable outlet headers shall be provided with a valve assembly that includes a detachable outlet seal cap, chained or otherwise attached to the body of the valve.

(*g*) Materials and fabrication procedures for portable outlet headers shall comply with paragraphs (a)(4) (i), (ii), and (v) of this section.

(*h*) Portable outlet headers shall be provided with frames which will support the equipment securely in the correct operating position and protect them from damage during handling and operation.

(v) *Manifold operating procedures.* (*a*) Cylinder manifolds shall be installed under the supervision of someone familiar with the proper practices with reference to their construction and use.

(*b*) All component parts used in the methods of manifolding described in subdivision (i) of this subdivision shall be approved as to materials, design and construction either separately or as an assembled unit.

(*c*) All manifolds and parts used in methods of manifolding shall be used only for the gas or gases for which they are approved.

(*d*) When acetylene cylinders are coupled, approved flash arresters shall be installed between each cylinder and the coupler block. For outdoor use only, and when the number of cylinders coupled does not exceed three, one flash arrester installed between the coupler block and regulator is acceptable.

EXHIBIT E

PLAN FOR METRIC SAFETY FORUMS

1. Criteria for participation.

Participants should have:

- Knowledge of the safety issues for the occupations to be studied
- Active safety training programs
- Interest or awareness of metric conversion issues.

2. Preparation for participants.

Each participant will be provided with:

- A letter of explanation for the forum
- Background information for the study
- The study plan
- A list of questions to be raised at the forum.

3. Forum Structure.

- Ideally forums will be sponsored by university departments with safety programs by professional associations.
- Meetings will be limited to researchers, sponsors, and four to six forum participants.
- Meetings will address each issue in a question and answer format.
- Forums will last no longer than one day and will be scheduled at a time mutually agreeable to researchers, sponsors, and participants.

4. Forum Content.

The content of the forum will follow the outline listed below.

EXHIBIT F

METRIC SAFETY HAZARDS STUDY

One-Day Forum Tentative Outline

1. Welcome and Study Background

2. Review of Occupational Areas and Population/Hazard Data

3. Discussion of Job/Task Analysis and Job Safety Analysis Data for Selected Occupations

4. Discussion of Metric Conversion Issues in Job/Tasks for Selected Occupations

5. Identification of Specific Potential Safety Hazards

6. Consideration of Preventive Mechanisms for Metric Safety Hazards and Associated Costs of Those Mechanisms

7. Identification of Associated Public Hazards

EXHIBIT G

IDEALIZED ANALYTICAL APPROACH

<u>Select Occupation(s)</u>	Based upon prioritization
<u>Job/Task Hazard Analysis</u>	What hazards exist?
<u>Metric Change Analysis</u>	What units change?
<u>Hazard Change Analysis</u>	How does unit change impact hazard?
<u>Sensitivity Analysis</u>	How sensitive to "SI" abuse?
<u>Recommendations</u>	What can USMB do?

Example I

Occupation:	Welder
Task:	Adjust tank pressure on oxygen and acetylene tanks and reads gauge to determine pressure
Hazard:	Wrong pressure makes gas mixture burn improperly... may EXPLODE!
Metric Change:	Gauge changes from PSI to KPa*
Hazard Change:	Unknown at this time

* See Exhibit H for examples of unit changes.

Example II

Occupation:	Machine tool operator
Task:	Set cutting speed and feed rates and uses dial settings to make adjustment based upon material and cutting tool
Hazard:	Wrong setting can cause piece to KICKBACK.
Metric Change:	Rates change from ft/min to m/min and in/rev to mm/rev*
Hazard:	Unknown at this time

Example III

Occupation:	Auto mechanic
Task:	Inflate tire to correct pressure
Hazard:	Over inflation may cause injury to worker

Metric Change:

Customary gauge	10 PSI to 80 PSI
Normal reading	28 PSI
SI metric gauge	60 KPa to 600 KPa
Normal reading	193 KPa

There exists a non "SI" but metric gauge that reads in 10,000(s) Pa. Its range is from 6 to 60.

If inflated to 28 by mistake, 28 x 10,000 Pa = 280 KPa or 40.6 PSI.

Change:	Unknown at this time

EXHIBIT H

EXAMPLES OF METRIC CHANGE SHOWING UNITS AND RANGES

Units	Now	Metric
Weight	50 lbs.	22.7 kg
	100 lbs.	45.4 kg
	2.5 tons	2.27 Mg or 2.27 TONS
Height	8 ft	2.44 m
	12 ft 4 in	3.76 m
Volume	5 gal	18.9 l
Flow rate	100 gal/hour	6.3 l/min
	5 gal/min	18.9 l/min
	10 cu ft/hour	4.7 l/min
Torque	75 ft/lbs	102 NM
	100 ft/lbs	136 NM
	50 in oz	353 M-mm
Temperature	32° F	0° C
	212° F	100° C
	1000° F	538° C
Pressure	30 PSI	207 KPa*
	100 PSI	690 KPa
	3000 PSI	20,690 KPa
	30 in - H_2O	7.5 KPa
	20 in - Hg	68 KPa
	10 ft - H_2O	29.9 KPa
Cutting speeds	30 ft/min	9.1 m/min
	110 ft/min	33.5 m/min
	250 ft/min	76.2 m/min
	350 ft/min	106.7 m/min
Feed rates	.012 in/rev	.3048 mm/rev
	.008 in/rev	.2032 mm/rev
	.003 in/rev	.0762 mm/rev
	.004 in/rev	.1016 mm/rev
	.006 in/rev	.1524 mm/rev
	.020 in/rev	.5080 mm/rev

* Many U.S. industries want to use the BAR for pressure, i.e., 207 KPa = 2.07 BAR

MRC/USMB ADVISORY PANEL MEETING SUMMARY

Safety Study

26 October 1981 - 9:00 A.M. - Marriott Hotel, Arlington, Virginia

The Advisory Panel attendees were Mr. Harry Goetz, Dr. Jim Johnson, Mr. Darrell Spencer, Mr. Ray Seifert, and Dr. Bob Semonisck. Also attending was Mr. George Smith of the International Brotherhood of Electrical Workers. Present from MRC were Judith LeFande, Joe Pokorney, Patti Lemon, and Dorothy Leedom. Present from the USMB were Dan Hoagland and Ed McEvoy.

The Metric Safety Hazard Advisory Panel met in Arlington, Virginia on October 26, 1981, to consider the draft project plan that had been developed by the MRC research staff. In addition, the Panel members expanded the number of data sources by recommending the involvement of various professional associations, labor organizations, and insurance companies that focus on industrial hazards.

The Panel received and marked up copies of the Hazard/Measurement Sensitive Occupations matrix. It was intended as a tool to obtain the experts" opinions on prioritization of the occupations to be studied. In addition, the Panel members agreed that occupation factors -- such as decisionmaking required, size of worker population, and potential for associated public hazard -- should be included in identifying the occupations to be studied.

The Panel agreed that, due to the hypothetical flavor of the study, it is appropriate to use a forum structure for field data gathering. The forums will, to the extent possible, cover different geographical areas, and be sponsored by schools of engineering and safety or by professional safety associations. The forum criteria and structure were discussed. An outline of these is attached.

The Panel recommended that contact be made with the National Education Association; the American Industrial Hygienists Association; Federal Aviation Administration; DoD (particularly the Army for aviation information); the ANMC training sector; and forestry, fishing, mining, and utility organizations.

The meeting closed with an agreement that the Panel members would review the data and analyses as requested, and would communicate as a group by teleconference or in another meeting if necessary.